4a. Gulf of Alaska Dover Sole

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Executive Summary

Changes in the Input Data

1) The 2005 fishery catch through Sept. 24, 2005 was incorporated in the model.
2) The 2004 fishery catch and length compositions were updated.
3) The 2005 GOA groundfish survey biomass estimate and length composition data were added to the model. Survey biomass decreased from 99,297 t in 2003 to 80,537 t in 2005. Survey biomass estimates and length compositions were recalculated for all survey years.

Changes in the Assessment Model

No changes were made to the model structure.

Changes in the Assessment Results

1) The recommended ABC, based on an $F_{40\%}$ harvest level of 0.142, is 8,482 t for 2006 and 8,494 t for 2007.
2) The OFL, based on an $F_{35\%}$ harvest level of 0.184, is 10,764 t for 2006 and 10,778 t for 2007.
3) Projected female spawning biomass is estimated at 41,922 t for 2006 and 42,262 t for 2007.
4) Total biomass (age 3+) is estimated at 132,297 for 2006 and 134,079 t for 2007.

SSC Comments Specific to the Dover Sole Assessments

SSC comment: "*The SSC noted inconsistencies in the presentation of material in the rex and Dover sole sections. Some material in the executive summary was not presented elsewhere in the section, citations to some references at the end of the section were missing, and inconsistencies between tables and data sources and years and text describing which years of data were used. A section for data gaps and research priorities was in the Dover sole section but did not contain any material.*

Author response: We have endeavored to eliminate the inconsistencies noted.

SSC comment: *Tables of trawl survey estimates need to more clearly indicate depth ranges for each survey.*"

Author response: We have added a column of depth ranges to the tables of trawl survey estimates.

SSC Comments on Assessments in General

SSC comment: The SSC requested that "stock assessment authors exert more effort to address each item contained in" a previously-defined list of items to be included in each SAFE chapter at its December 2004 meeting

Author response: We have endeavored to incorporate the list of requested items in the current SAFE chapter.

SSC comment: The SSC encouraged authors to consider adding more detailed ecosystem consideration information in the flatfish chapters and exploring survey catchability and temperature relationships.

Author response: This was not feasible because a new principal author assumed responsibility for the SAFE chapter this year. However, the author will make every endeavor to do so during the next year.

Introduction

Dover sole (*Microstomus pacificus*) occur from Northern Baja California to the Bering Sea and the western Aleutian Islands; they exhibit a widespread distribution throughout the Gulf of Alaska (Miller and Lea, 1972; Hart, 1973) . Adults are demersal and are mostly found at depths from 300 m to 1500 m.

Dover sole are batch spawners; spawning in the Gulf of Alaska has been observed from January through August, peaking in May (Hirschberger and Smith, 1983). The average 1 kg female may spawn it 83,000 advanced yolked oocytes in about 9 batches (Hunter et al., 1992). Although the duration of the incubation period is unknown, eggs have been collected in plankton nets east of Kodiak Island in the summer (Kendall and Dunn, 1985). Larvae are large and have an extended pelagic phase that averages about 21 months (Markle et al., 1992). They have been collected in bongo nets only in summer over mid-shelf and slope areas in the Gulf. The age or size at metamorphosis is unknown, but pelagic postlarvae as large as 48 mm have been reported and juveniles may still be pelagic at 10 cm (Hart, 1973). Juveniles less than 25 cm are rarely caught with the adult population in bottom trawl surveys (Martin and Claussen, 1995).

Dover sole move to deeper water as they age and older female Dover sole may have seasonal migrations from deep water on the outer continental shelf and upper slope where spawning occurs to shallower water mid-shelf in summer time to feed (tagging data from California to British Columbia, Demory et al. 1984, Westrheim et al. 1992). Older male Dover sole may also migrate seasonally but to a lesser extent than females. The maximum observed age for Dover sole in the Gulf of Alaska is 54 years.

Fishery

Flatfish species in the Gulf of Alaska have been managed as a unit that includes the major species inhabiting the region except for Pacific halibut: arrowtooth flounder, flathead sole, northern and southern rock sole, rex sole, Dover sole, yellowfin sole and starry flounder. In 1990, the North Pacific Fisheries Management Council divided the flatfish assemblage into four categories for management: arrowtooth flounder, flathead sole, “shallow water flatfish” and “deep water flatfish”. The first two of these are single species, while the latter two are species complexes. Dover sole was placed in the “deep water flatfish” group, along with rex sole (*Glyptocephalus zachirus*), Greenland turbot (*Reinhardtius hippoglossoides*) and deep-sea sole (*Embassichthys bathybius*). The action by the Council was taken because of the significant difference in halibut bycatch rates in the directed fisheries targeting deep-water and shallow-water flatfish. In 1993, the Council removed rex sole from the deep-water management category due to concerns over bycatch of Pacific ocean perch in the rex-sole target fishery, and the deep-water flatfish complex comprises the remaining three species: Dover sole, Greenland turbot and deep-sea sole. Within the complex, Dover sole is by far the biomass dominant in the catch, accounting for typically 98% of the total catch in biomass.

Since passage of the MFMCA in 1977, the flatfish fishery in the Gulf of Alaska has undergone substantial changes. Until 1981, annual harvests of flatfish were around 15,000 t, taken primarily as bycatch by foreign vessels targeting other species. Foreign fishing ceased in 1986 and joint venture fishing began to account for the majority of the catch. In 1987, the gulf-wide flatfish catch increased nearly fourfold , with joint venture fisheries accounting for all of the increase. Since 1988, only domestic fishing fleets are allowed to harvest flatfish. As foreign fishing ended, catches decreased to a low of 2,441 t in 1986. Catches subsequently increased under the joint venture and then domestic fleets to a high of 43,107 t in 1996. Catches then declined to 23,237 t in 1998 and were 22,700 t in 2004.

Focusing mode specifically now on Dover sole, in the Gulf of Alaska this species is caught in a directed fishery using bottom trawls. Fewer than 20 shore-based catcher-type vessels participate in this fishery, together with about 6 catcher-processor vessels. Recruitment to the fishery begins at about age 10.

Fishing seasons are driven by seasonal halibut PSC apportionments, with fishing occurring primarily in April and May because of higher catch rates and better prices.

Dover sole are also caught in pursuit of other bottom-dwelling species as bycatch. They are caught as bycatch in Pacific cod, bottom pollock and other flatfish fisheries, and are caught along with these species in the deep-water flatfish-directed fishery. The gross discard rate for Dover sole over all fisheries in 2004 was 21%, a decrease from 50% in 2003.

Historically, catches of Dover sole increased dramatically from a low of 23 t in 1986 to a high of almost 10,000 t in 1991 (Table 4a.1, Figure 4a.1). Following that high, catches have declined rather steadily, with perhaps a 6-year cycle imposed on the overall trend. The catch in 2005 (400 t as of Sept. 24) is the lowest since 1987.

Annual catches of Dover sole have been well below TACs in recent years, although the population appears to be capable of supporting higher exploitation rates (Table 4a.2). Limits on catch in the deep-water flatfish complex are driven by within-season closures of the directed fishery due to restrictions on halibut PSC, not attainment of the TAC (Table 4a.3).

Data

Fishery Data

This assessment uses fishery catches from 1984 through 24 September, 2005 (Table 4a.1; Figure 4a.1), as well as estimates of the proportion of individuals caught by length group and sex for the years 1985-2005 (Table 4a.4). Sample sizes for the size compositions are shown in Table 4a.5.

Survey Data

Because Dover sole is often taken incidentally in target fisheries for other species, CPUE from commercial fisheries seldom reflects trends in abundance for this species. It is therefore necessary to use fishery-independent survey data to assess the condition of this stock.

This assessment uses estimates of total biomass for Dover sole in the Gulf of Alaska from triennial (1984-1999) and biennial (2001-2005) groundfish surveys conducted by the Alaska Fisheries Science Center's Resource Assessment and Conservation Engineering (RACE) Division to provide indices of population abundance (Table 4a.6; Figure 4a.2). Survey coverage in both depth range and geographical area has varied among years and requires careful consideration of the survey results (Tables 4a.7-8). Survey coverage was limited to less than 500 m depths in 1990, 1993, 1996 and 2001 but extended to 1000 m in 1984, 1987, 1999 and 2005 (the survey extended to 700 m in 2003). In 2001, the survey was not conducted in the eastern portion of the Gulf of Alaska. Turnock et al. (2003a) developed correction factors to scale "raw" survey results for differences in availability caused by differences in survey coverage, and both uncorrected and corrected estimates are presented in Table 4a.6. On average, about 18% of Dover sole biomass is at depths greater than 500 m, while the eastern portion of the Gulf accounts for nearly 50% of the biomass (Turnock et al., 2003a; Tables 4a.7-8).

Since 1984, survey estimates of total biomass have fluctuated about a mean of ~87,000 t. After starting relatively low at 68,000 t in 1984, the survey-estimated biomass jumped to a maximum of 117,000 t (corrected for availability) in 1990, followed by declining estimates through the rest of the decade. Survey biomass increased to 99,000 t in 2003. The estimated survey biomass was 80,537 t in 2005, about 20% smaller than the 2003 estimate.

Estimates of age and size composition from the RACE surveys were also incorporated in the assessment model. Estimates of numbers-at-age were available for 1993, 1996, 1999 and 2001 (Table 4a.9). Estimates of the numbers-by-length group were available for each survey year, but were used only when age composition data was not available (1987, 1990, 1999, 2001 and 2005; Table 4a.10). Sample sizes for the age and size compositions are shown in Table 4a.5.

Analytic Approach

Model structure

The assessment was conducted using a split-sex, age-structured model with parameters evaluated in a maximum likelihood context. The model structure (Appendix A) was developed following Fournier and Archibald's (1982) methods, with many similarities to Methot (1990). We implemented the model using automatic differentiation software developed as a set of libraries under C++ (ADModel Builder). ADModel Builder can estimate a large number of parameters in a non-linear model using automatic differentiation software extended from Greiwank and Corliss (1991) and developed into C++ class libraries. This software provides the derivative calculations needed for finding the minimum of an objective function via a quasi-Newton function minimization routine (e.g., Press et al. 1992). It also gives simple and rapid access to these routines and provides the ability to estimate the variance-covariance matrix for all parameters of interest.

Age classes included in the model run from age 3 to 40. Age at recruitment was set at 3 years in the model due to the small number of fish caught at younger ages. The oldest age class in the model, age 40, serves as a plus group in the model; the maximum age of Dover sole based on otolith age determinations has been estimated at 54 years (Turnock et al., 2003). Details of the population dynamics and estimation equations, description of variables and likelihood components are presented in Appendix A (Tables A.1, A.2, and A.3). Model parameters that are typically fixed are presented in Table A.4. A total of 97 parameters were estimated in the final model (Table A.5).

Parameters estimated independently

Model parameters related to natural mortality, growth, weight, maturity and survey catchability (Table A.4) were fixed in the final model.

Natural mortality

As in the previous assessment (Turnock et al., 2003a), natural mortality (M) was fixed at 0.085 yr^{-1} for both sexes in all age classes. This estimate was based on Hoenig's (1983) method and a maximum observed age of 54 years.

Growth

Mean length-at-age, L_t, was modeled as:

$$L_t = L_{\inf}\left(1 - e^{-k(t-t_0)}\right)$$

Survey age and length data from 1984, 1993, 1996, 1999 and 2001 were used to estimate the parameters. L_{inf} was estimated at 51.51 cm for females and 42.42 cm for males (Figure 4a.4). The growth parameter k was estimated at 0.127 for females and 0.195 for males, while t_0 was -2.66 for females and -1.97 for males.

The estimated length-at-age relationship was used to convert model age compositions to estimated size compositions, based on sex-specific age-length transition matrices (Table 4a.11). The transition matrices used were identical to those used in the previous assessment (Turnock et al., 2003a).

Weight-at-length

The weight-length relationship used for Dover sole was identical to that used in the previous assessment (Turnock et al., 2003a): $W = 0.0029\ L^{3.3369}$ for both sexes (weight in grams and length in centimeters; Abookire and Macewicz, 2003). Weight-at-age (Table 4a.12) was estimated using the mean length-at-age and the weight-length relationship.

Maturity

The maturity schedule for Gulf of Alaska Dover sole was estimated using histological analysis of ovaries collected in 2000 and 2001 (Abookire and Macewicz, 2003; Table 4a.12). A total of 273 samples were analyzed for estimation of age at maturity. Size at 50% mature was estimated to be 43.9 cm with a slope of 0.62 cm^{-1} from a sample of 108 fish. Age at 50% mature was 6.7 years with a slope of 0.880 yr^{-1}. Minimum-age at-maturity was 5 years.

Survey catchability

For the assessment, survey catchability (Q in Table A.1) was fixed at 1. An alternative model with Q allowed to vary was explored, but estimability was poor (see below).

Parameters estimated conditionally

A total of 97 parameters were estimated in the final model (Table A.5). These consist primarily of parameters on the recruitment of Dover sole to the population (60 parameters total, including ones determining the initial age composition) and values related to annual fishing mortality (23 parameters total).

The separable age-component of fishing mortality was modeled using a two parameter ascending logistic function estimated separately for males and females (4 parameters total). The same form of curve was also used to estimate relative age-specific survey selectivity. However, two sets of curves were estimated: one set corresponding to surveys with full depth coverage (> 500 m) and the second set corresponding to surveys that only sampled shallow (1-500 m) areas. Thus, 8 parameters were used to estimate survey selectivity.

Annual recruitment to the age 3 year class was parameterized in the model using one parameter for the log-scale mean recruitment and 40 parameters for the annual log-scale deviation from the mean. Recruitments were estimated back to 1947 to provide an initial age distribution for the model in its starting year (1984). In an analogous fashion, fully-recruited fishing mortality was parameterized in the model using one parameter for the log-scale mean and 22 parameters for the annual log-scale deviation from the mean.

Parameters in the model were selected based on minimizing an objective function equivalent to a negative log-likelihood function, hence the parameter estimates are maximum likelihood estimates. Components that contribute to the overall (-log) likelihood include those related to observed fishery catches, fishery size compositions, survey biomass estimates, survey size compositions, survey age composition, and recruitment deviations (Table A.3). The observed fishery catch was assumed to have a lognormal error structure, as was estimated survey biomass. The size and age compositions were assumed to be drawn from different sex-specific multinomial distributions. The recruitment deviation parameters were incorporated directly into the overall likelihood via three components: “early” recruitment, “ordinary” recruitment and “late” recruitment (Table A.3). This allows different weights in the likelihood function to be for recruitment estimates that are not well observed in the data (i.e., recruitments prior to the model period or the most recent ones). The “early” recruitment component incorporated deviations from 1947 to 1983 (i.e., prior to the modeled age structure), “ordinary” recruitment incorporated deviations from 1984-2002 and “late” recruitment incorporated deviations from 2003-2005. All three components were formulated assuming a lognormal error structure.

Different weights can be assigned to each likelihood component to increase or decrease the relative degree of model fit to the data underlying the respective component; a larger weight induces a closer fit to a given likelihood component. Typically, a relatively large weight (e.g., 30) is applied to the catch component while smaller weights (e.g., 1) are applied to the survey biomass, recruitment, and size and age composition components. This reflects a belief that total catch data are reasonably well known (smaller variance) than the other types of data. For the recruitment components, larger weights applied to a component force the deviations contributing to that component closer to zero (and thus force recruitment closer to the geometric mean over the years that contribute to the component).

Model evaluation

In performing this assessment, we considered several alternative model configurations. To establish a baseline for the contrast among likelihood weights, we assigned a weight of 1 to the survey biomass component (Table 4a.13). We also assigned a weight of 1 to the survey age composition and "normal" recruitment components. Model-predicted length compositions are not expected to fit the data as well as age compositions should due to the inherent "smearing" of ages among length bins inherent in the use of age-length transition matrices to convert from age to length compositions. The length composition-associated components (fishery and survey) were thus assigned weights of 0.5, down-weighting their importance relative to the survey biomass and age composition fits. We assigned higher weights (2 and 3, respectively) to the "early" and "late" recruitment components to keep the associated recruitments close to the long-term median, but allowed more variation in the "normal" recruitment constituents by assigning the associated likelihood component a weight of 1. Finally, we assigned a weight of 30 to the catch-specific likelihood component to assure a close fit between model-predicted and input catch values, under the assumption that catch is measured with little uncertainty.

Based on results from the 2003 assessment which indicated that estimating survey catchability was problematic, we also fixed survey catchability as a constant in the model (Q =1). Initial values for the remaining parameters were set as listed in Table 4a.14. To test whether the resulting model solution (Table 4a.15) was indeed a global, rather than local, maximum on the likelihood surface, we conducted a Markov Chain Monte Carlo (MCMC) study using ADModel Builder's built-in MCMC capability in which we evaluated the likelihood at 1000 different parameter combinations and compared the resulting values with that from the model solution. The results of this study indicated that the model solution was in fact a global maximum. We further tested the convergence of the solution by starting the model with several different parameter sets (Table 4a.15). Model runs 1 and 2 converged to the same final solution as the baseline case, providing additional evidence that the original solution was indeed the global maximum. Model run 3 resulted in estimates at the lower bounds of several parameters and was considered unreliable.

In addition to the baseline case, we reconsidered the case in which Q was allowed to vary (between 0.1 and 10), rather than being fixed at 1. All other settings were identical to the baseline case. This resulted, as in the 2003 assessment, in Q being driven to its lower limit—an unacceptable result indicating that Q was not estimable given the data. Consequently, we have chosen to follow previous assessments and use the baseline case with Q fixed at 1.

Final parameter estimates

The parameter estimates considered final for this assessment are given in Table 4a.15 for all model parameters.

Schedules implied by parameter estimates

The estimated selectivity curves for the fishery and surveys are shown in Figure 4a.5. For the fishery, the selectivity curves rise extremely steeply and approximate knife-edge selection. The age at 95% selection is 13.5 for females and 11.0 for males.

The selectivity curves estimated for the two survey types (shallow and full coverage) differ from those of the fishery, as well as from one another (Figure 4.a5). For both survey types, recruits (age 3) of either sex are 20% selected. For the shallow survey type, selectivity for males increases rapidly with age—age at 95% selection is 6—while it increases much less rapidly for females—age at 95% selection is 25.6. For the full coverage survey type, selectivity increases slowly with age for both sexes—age at 95% selection is 34.9 for males and 43.4 for females. Similar results were obtained in the 2003 assessment (Turnock et al., 2003a).

Results

Given the large relative weight assigned to the catch-specific likelihood component, it was not surprising that the model estimates of fishery catch closely matched the observed values (Table 4a.16 and Figure 4a.6). The model did not fit the fishery size compositions nearly as well, although its performance appeared to be reasonably good in most years (Figures 4a.7-8 for females and males, respectively). Fits to the fishery size compositions were poorest when the observed size composition was dominated by a single size class and thus sharply peaked (e.g., 1991 in Figure 4a.7). The smoothing inherent in using an age-length transition matrix to convert age classes to size classes precludes close fits to peaked size compositions.

The model does not fit observed survey biomass values as closely as it does the catch (Table 4a.16 and Figure 4a.9). The model overestimates survey biomass in the early portion of the time series (1984-1996) and underestimates it in the latter portion (2003-2005).

As with the fishery size compositions, model fits to the survey size compositions were poorest when the observed size compositions were sharply peaked, but still generally reasonable (Figures 4a.10-11). Finally, the model also fits the survey age composition reasonably well (Figures 4a.12 -13), although more so at younger ages (less than 20). The model appears to mainly underestimate the size fraction at older ages. Part of the lack of fit at older ages may be due to the 5-year age bins used for ages > 20.

The model also estimates other population variables of interest, such as time series of total biomass, spawning biomass, recruitment and fully-selected fishing mortality. In this assessment, total biomass is represented by age 3+ biomass and spawning biomass is female spawning biomass. Model estimates indicate that total biomass began relatively high in the 1980s (~170,000 t) but declined gradually through the 1990's, reaching a low of 115,000 t in 2001 (Table 4a.17 and Figure 4a.14). Since 2001, total biomass appears to be increasing moderately and is estimated at 130,000 t for 2005. Total biomass estimated in this assessment agrees well with that from the 2003 assessment in the 1980's, but the estimates diverge for more recent years. The biomass estimated in the current assessment is always higher than that from the 2003 assessment—for 2003, the current assessment's estimate of total biomass is 28% larger than that in the 2003 assessment.

Model estimates of spawning biomass show a pattern somewhat different from that of total biomass (Table 4a.17, Figure 4a.14). Spawning biomass increased somewhat through the 1980's and peaked in 1991 at 64,000 t. Subsequently, spawning biomass has steadily declined; the estimate for 2005 (42,000 t) is the lowest in the model time period, corresponding to a decrease of 34% from the maximum in 1991. When compared with the 2003 assessment, estimated female spawning biomass is consistently higher in this assessment—but not to the extent that total biomass was higher.

The temporal patterns of recruitment estimated by the model were quite similar to those from the 2003 assessment, although average recruitment from 1984-2003 was 39% higher in the current model. Model estimates of annual recruitment (age 3 numbers) ranged from a low of 7 million in 1995 to a high of 45 million in 2002 (Table 4a.18, Figure 4a.15). Turnock et al. (2003a) suggested that the 2003 survey length compositions indicated a potentially large recruitment event which may also have been reflected by the increase in survey biomass from 2001 to 2003 (77,200 [corrected for availability] and 99, 297 t, respectively; Table 4a.6). However, the uncertainty associated with the 2002 recruitment estimate was large as well (the cv for the estimate was 0.66). This may reflect competing influences in the data, since there is little indication of a strong 2002 recruitment in the 2005 survey length composition (Figures 4a.10-11) or the 2005 survey biomass, which declined to close to the 2001 level (Table 4a.6). Further data is required to confirm or repudiate the model's estimate.

A control rule plot showing the temporal trajectory of estimated fishing mortality and spawning biomass indicates that the GOA Dover sole stock has not been overfished nor has overfishing occurred (Figure 4a.16). Based on the trajectory, the stock does not appear to have been overfished or to have experienced overfishing in the past.

Although we regarded the preceding as the "accepted model" (AM), we were also concerned regarding the large uncertainty associated with the recruitment estimated for 2002 (the largest in the time series) and its implications for future harvests. As a precautionary measure, we reran the model with the 2002-2005 recruitments constrained to be near the long-term median to evaluate the effect of the estimated high recruitment on our assessment. Results from this "constrained recruitment" model (CRM) were similar to those from our "accepted model" except, largely, for the constrained recruitments themselves (Figures 4a.17-18). The values of $F_{40\%}$ and $F_{35\%}$ for the CRM were identical to those of the AM because these were derived from a "per recruit" analysis that does not depend on the total number of recruits. Because mean recruitment was reduced in the CRM relative to the AM (by 8% in the mean), the CRM estimates for $B_{40\%}$ and $B_{35\%}$ are comparatively reduced, as well. The projected catch in 2006 assuming fishing at $F_{40\%}$ (F_{maxABC}) is nearly identical for the two models (8,482 t for the AM and 8,493 t for the CRM). Over the near-term (2-3 years), projected population trajectories under the AM and CRM were similar because the substantial difference between the two models is the presence/absence of high recruitment in 2002-2003—and it will take several years before these recruits would appear in the fishery or in the spawning biomass. In the meantime, another groundfish survey will be conducted in 2007; the results from this survey should allow us to increase the precision in the size of the age class that recruited in 2003.

Projections and Harvest Alternatives

The reference fishing mortality rate for Dover sole is determined by the amount of reliable population information available (Amendment 56 of the Fishery Management Plan for the groundfish fishery of the Bering Sea/Aleutian Islands). Estimates of $F_{40\%}$, $F_{35\%}$, and $SPR_{40\%}$ were obtained from a spawner-per-recruit analysis. An estimate of $B_{40\%}$ can be calculated as the product of $SPR_{40\%}$ times the equilibrium number of recruits. Assuming that the average recruitment from the 1984-2005 year classes estimated in this assessment represents a reliable estimate of equilibrium recruitment, then $B_{40\%}$ is 21,607 t for the AM and 19,940 for the CRM. The estimated 2006 spawning stock biomass is nearly identical for the two models: 41,922 t for the AM and 41,959 for the CRM. Since reliable estimates of the 2006 spawning biomass (B), $B_{40\%}$, $F_{40\%}$, and $F_{35\%}$ exist and B>$B_{40\%}$ (41,922 t > 21,607 t), the Dover sole reference fishing mortality is defined in Tier 3a. For this tier, F_{ABC} is constrained to be ≤ $F_{40\%}$, and F_{OFL} is defined to be $F_{35\%}$. The values of these quantities are:

Quantity	Accepted Model	Constrained Recruitment Model
2006 SSB estimate (*B*)	41,922 t	41,959
$B_{40\%}$	21,607 t	19,940
$F_{40\%}$	0.142	0.142
F_{ABC}	0.142	0.142
$B_{35\%}$	19,906 t	17,448
$F_{35\%}$	0.184	0.184
F_{OFL}	0.184	0.184

Because the Dover sole stock has not been overfished in recent years and the stock biomass is relatively high, we do not recommended to adjust F_{ABC} downward from its upper bound.

The maximum ABC for 2006 was essentially the same for both the AM and CRM: 8,482t and 8,493 t, respectively. In the interest of applying a consistent cautionary approach, we chose the lower value of 8,482 t as our recommended ABC. Similarly, the 2006 OFL was nearly identical for the two models: 10,764 t for the AM and 10,778 t for the CRM.

A standard set of projections is required for each stock managed under Tiers 1, 2, or 3 of Amendment 56. This set of projections encompasses seven harvest scenarios designed to satisfy the requirements of Amendment 56, the National Environmental Policy Act, and the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA).

For each scenario, the projections begin with the vector of 2005 numbers at age estimated in the assessment. This vector is then projected forward to the beginning of 2006 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2005. In each subsequent year, the fishing mortality rate is prescribed on the basis of the spawning biomass in that year and the respective harvest scenario. In each year, recruitment is drawn from an inverse Gaussian distribution whose parameters consist of maximum likelihood estimates determined from recruitments estimated in the assessment. Spawning biomass is computed in each year based on the time of peak spawning and the maturity and weight schedules described in the assessment. Total catch is assumed to equal the catch associated with the respective harvest scenario in all years. This projection scheme is run 1000 times to obtain distributions of possible future stock sizes, fishing mortality rates, and catches.

Five of the seven standard scenarios will be used in an Environmental Assessment prepared in conjunction with the final SAFE. These five scenarios, which are designed to provide a range of harvest alternatives that are likely to bracket the final TAC for 2006, are as follow ("*max* F_{ABC}" refers to the maximum permissible value of F_{ABC} under Amendment 56):

> *Scenario 1*: In all future years, F is set equal to *max* F_{ABC}. (Rationale: Historically, TAC has been constrained by ABC, so this scenario provides a likely upper limit on future TACs.)
>
> *Scenario 2*: In all future years, F is set equal to a constant fraction of *max* F_{ABC}, where this fraction is equal to the ratio of the F_{ABC} value for 2006 recommended in the assessment to the *max*

F_{ABC} for 2006. (Rationale: When F_{ABC} is set at a value below *max* F_{ABC}, it is often set at the value recommended in the stock assessment.)

Scenario 3: In all future years, F is set equal to 50% of max F_{ABC}. (Rationale: This scenario provides a likely lower bound on F_{ABC} that still allows future harvest rates to be adjusted downward when stocks fall below reference levels.)

Scenario 4: In all future years, F is set equal to the 2001-2005 average F. (Rationale: For some stocks, TAC can be well below ABC, and recent average F may provide a better indicator of F_{TAC} than F_{ABC}.)

Scenario 5: In all future years, F is set equal to zero. (Rationale: In extreme cases, TAC may be set at a level close to zero.)

The recommended F_{ABC} and the maximum F_{ABC} are equivalent in this assessment, so scenarios 1 and 2 yield identical results. The 12-year projections of the mean harvest, spawning stock biomass and fishing mortality using the AM results for the five scenarios are shown in Table 4a.19-21.

Two other scenarios are needed to satisfy the MSFCMA's requirement to determine whether the Dover sole stock is currently in an overfished condition or is approaching an overfished condition. These two scenarios are as follows (for Tier 3 stocks, the MSY level is defined as $B_{35\%}$):

Scenario 6: In all future years, F is set equal to F_{OFL}. (Rationale: This scenario determines whether a stock is overfished. If the stock is expected to be above its MSY level in 2006, then the stock is not overfished.)

Scenario 7: In 2006 and 2007, F is set equal to *max* F_{ABC}, and in all subsequent years, F is set equal to F_{OFL}. (Rationale: This scenario determines whether a stock is approaching an overfished condition. If the stock is expected to be above its MSY level in 2018 under this scenario, then the stock is not approaching an overfished condition.)

The results of these two scenarios indicate that the Dover sole stock is not overfished and is not approaching an overfished condition (Tables 4a.19-21). With regard to assessing the current stock level, the expected stock size in the year 2006 of scenario 6 is 2.1 times its $B_{35\%}$ value of 19,906 t, thus the stock is not currently overfished. With regard to whether the stock is approaching an overfished condition, the expected spawning stock size in the year 2018 of scenario 7 (22,727 t) is greater than its $B_{35\%}$ value; thus, the stock is not expected to fall below *MSY* within two years. Similar conclusions were obtained from projections using the CRM results.

Estimating an ABC and OFL for 2007 is somewhat problematic as these values depend on the catch that will be taken in 2006. The actual catch taken in the GOA Dover sole fishery has been substantially smaller than the TAC for the past several years, and the 2005 catch was the smallest in recent years. To be conservative, we assumed that a reasonable estimate of the catch to be taken in 2006 was the five-year average of recent catches (624 t). Using this value and the estimated population size at the start of 2006 from the MA or CRM, we projected the stock ahead through 2006 and calculated the ABC and OFL for 2007.

The 2007 ABC and OFL were nearly identical for the AM and CRM, as they were for 2006. The maximum ABC for 2007 was estimated to be 8,494 t using the AM and 8,504 t using the CRM. The OFL was estimated to be 10,778 using the AM and 10,792 t using the CRM. Age 3+ biomass for 2007 was estimated at 134,076 t for the AM and 123,491 t for the CRM. Female spawning biomass was estimated at 42,262 t using the MA and 42,236 t using the CRM. Applying the same precautionary approach we used to recommend the 2006 ABC and OFL, we adopted the lower ABC and OFL for 2007 obtained using the AM. Thus, our recommended ABC for 2007 is 8,494 t and OFL is 10,778 t.

ABC allocation by management area

TAC's for Dover sole in the Gulf of Alaska are divided among four smaller management areas (Western, Central, West Yakutat and Southeast Outside). Similar to the 2003 assessment, the area-specific ABC's for Dover sole in the GOA are divided up over the four management areas by applying the fraction of 2005 survey biomass estimated for each area (relative to the total over all areas) to the 2006 and 2007 ABC's. The area-specific allocations for 2006 and 2007 are:

ABC Allocation by Management Area (t)					
Year	Western	Central	West Yakutat	Southeast Outside	Total ABC
2006	298	4,095	2,652	1,437	8,482
2007	299	4,101	2,655	1,439	8,494

Ecosystem Considerations

Ecosystem effects on the stock

Dover sole commonly feed on polychaetes worms, pelecypod and scaphapod mollusks, shrimp and brittle stars (Buckley et al., 1999). Trends in prey abundance for Dover sole are unknown.

Important predators include Pacific cod and most likely arrowtooth flounder. Arrowtooth flounder are currently the most abundant groundfish in the Gulf of Alaska, and have steadily increased in abundance since the early 1970's (Turnock et al., 2003b). Pacific cod abundance in the Gulf of Alaska has been declining since 1990 (Thompson et al., 2004). Although the continued increase in abundance of arrowtooth flounder may be cause for concern, the abundance of Dover sole appears to be increasing in recent years, as well. Predation by arrowtooth may be limiting the potential rate of increase of Dover sole under current conditions, but it does not appear to represent a threat to the stock.

Fishery effects on ecosystem

Small amounts of prohibited species such as halibut and crab are taken in the Dover sole-directed fishery. In 2004, the overall halibut PSC rate for the directed fishery was 218 kg halibut/t flatfish—an increase from the 2003 rate of 105. The PSC rate for salmon in the 2004 directed fishery was essentially 0 salmon/t flatfish (only 2 salmon were caught), a decrease from 1.92 salmon/t flatfish in 2003 (631 salmon caught). Crabs were not taken in the fishery in either 2003 or 2004.

Catches of Dover sole have been concentrated along the shelf edge east and southeast of Kodiak Island in the Gulf of Alaska over the past few years (Figure 4a.19).

Effects of discards and offal production on the ecosystem are unknown for the Dover sole fishery.

Data gaps and research priorities

The amount of age data for Dover sole in the Gulf of Alaska available from the groundfish survey is minimal, at best, and nonexistent from the fishery. Additional age data should improve future stock assessments by allowing improved estimates of individual growth and age-length transition matrices, and by filling in missing years with age composition data.

Further modeling research should address the use of length-based approaches to fishery and survey selectivity in the assessment model, as well as alternative forms for the selectivity function. In addition, spatially-explicit approaches that incorporate the differences in survey depth coverage among years should be considered. The utility of potential environmental predictors of recruitment (e.g., temperature) should also be investigated.

Summary

The following table summarizes the assessment results for GOA Dover sole:

Tier	3a	
Reference mortality rates		
M	0.085 yr^{-1}	
$F_{40\%}$	0.142	
$F_{35\%}$	0.184	
Equilibrium female spawning biomass		
$B_{100\%}$	54,017 t	
$B_{40\%}$	21,607 t	
$B_{35\%}$	19,906 t	
Fishing rates		
F_{OFL}	0.184	
F_{ABC} (maximum permissible)	0.142	
F_{ABC} (recommended)	0.142	
Projected biomass	**2006**	**2007**
Age 3+ biomass	132,297 t	134,079 t
Female spawning biomass	41,922 t	42,262 t
Harvest limits	**2006**	**2007**
OFL	10,764 t	10,778 t
ABC (maximum permissible)	8,482 t	8,494 t
ABC (recommended)	8,482 t	8,494 t

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Tables

Table 4a.1. Annual catch of Dover sole in the Gulf of Alaska, 1984-2005. 2005 catch is through Sept. 24, 2005.

year	catch (t)
1984	132
1985	43
1986	23
1987	56
1988	1,087
1989	1,521
1990	2,348
1991	9,741
1992	8,364
1993	3,804
1994	3,053
1995	2,082
1996	2,178
1997	3,659
1998	2,174
1999	2,263
2000	957
2001	536
2002	559
2003	946
2004	681
2005	400

Table 4a.2. Recent ABCs, TACs, OFLs and catch for deep-water flatfish. 2005 catch is as of Sept. 24, 2005.

Year	ABC (t)	TAC (t)	OFL (t)	Total Catch (t)	Changes to assessment measures
1995	14,590	11,080	17,040	2,082	
1996	14,590	11,080	17,040	2,178	
1997	7,170	7,170	9,440	3,659	
1998	7,170	7,170	9,440	2,174	
1999	6,050	6,050	8,070	2,263	
2000	5,300	5,300	6,980	957	
2001	5,300	5,300	6,980	536	
2002	4,880	4,880	6,430	559	
2003	4,880	4,880	6,430	946	
2004	6,070	6,070	8,010	681	Age-structured model adopted for assessment.
2005	6,820	6,820	8,490	400	

Table 4a.3. Recent closures of the deepwater flatfish fishery by management area. Open = fishery opens. Bycatch (hal.) = directed fishery closed due to halibut PSC limits.

	Western Gulf		Central Gulf		West Yakutat		Southeast
Year	Date	Measure	Date	Measure	Date	Measure	
2000	1-Jan	Bycatch	20-Jan	open	20-Jan	open	Closed to trawling
			13-May	bycatch (hal.)	13-May	bycatch (hal.)	
			4-Jul	open	4-Jul	open	
			23-Aug	bycatch (hal.)	23-Aug	bycatch (hal.)	
			1-Oct	open	1-Oct	open	
2001	20-Jan	open	20-Jan	open	20-Jan	open	Closed to trawling
	25-May	bycatch (hal.)	25-May	bycatch (hal.)	25-May	bycatch (hal.)	
	1-Jul	open	1-Jul	open	1-Jul	open	
	23-Jul	bycatch (hal.)	23-Jul	bycatch (hal.)	23-Jul	bycatch (hal.)	
	1-Oct	open	1-Oct	open	1-Oct	open	
2002	20-Jan	open	20-Jan	open	20-Jan	open	Closed to trawling
	24-May	bycatch (hal.)	24-May	bycatch (hal.)	24-May	bycatch (hal.)	
	30-Jun	open	30-Jun	open	30-Jun	open	
	2-Aug	bycatch (hal.)	2-Aug	bycatch (hal.)	2-Aug	bycatch (hal.)	
	1-Oct	open	1-Oct	open	1-Oct	open	
	13-Oct	bycatch (hal.)	13-Oct	bycatch (hal.)	13-Oct	bycatch (hal.)	
	6-Nov	open	6-Nov	open	6-Nov	open	
	10-Nov	bycatch (hal.)	10-Nov	bycatch (hal.)	10-Nov	bycatch (hal.)	
2003	20-Jan	open	20-Jan	open	20-Jan	open	Closed to trawling
	16-May	bycatch (hal.)	16-May	bycatch (hal.)	16-May	bycatch (hal.)	
	29-Jun	open	29-Jun	open	29-Jun	open	
	15-Oct	bycatch (hal.)	15-Oct	bycatch (hal.)	15-Oct	bycatch (hal.)	
2004	20-Jan	open	20-Jan	open	20-Jan	open	Closed to trawling
	19-Mar	bycatch (hal.)	19-Mar	bycatch (hal.)	19-Mar	bycatch (hal.)	
	1-Apr	open	1-Apr	open	1-Apr	open	
	26-Apr	bycatch (hal.)	26-Apr	bycatch (hal.)	26-Apr	bycatch (hal.)	
	4-Jul	open	4-Jul	open	4-Jul	open	
	25-Jul	bycatch (hal.)	25-Jul	bycatch (hal.)	25-Jul	bycatch (hal.)	
	1-Oct	open	1-Oct	open	1-Oct	open	
	1-Oct	bycatch (hal.)	1-Oct	bycatch (hal.)	1-Oct	bycatch (hal.)	
2005*	20-Jan	open	20-Jan	open	20-Jan	open	Closed to trawling
as of	23-Mar	bycatch (hal.)	23-Mar	bycatch (hal.)	23-Mar	bycatch (hal.)	
9/27/05	1-Apr	open	1-Apr	open	1-Apr	open	
	8-Apr	bycatch (hal.)	8-Apr	bycatch (hal.)	8-Apr	bycatch (hal.)	
	24-Apr	open	24-Apr	open	24-Apr	open	
	3-May	bycatch (hal.)	3-May	bycatch (hal.)	3-May	bycatch (hal.)	
	5-Jul	open	5-Jul	open	5-Jul	open	
	24-Jul	bycatch (hal.)	24-Jul	bycatch (hal.)	24-Jul	bycatch (hal.)	
	1-Sep	open	1-Sep	open	1-Sep	open	
	4-Sep	bycatch (hal.)	4-Sep	bycatch (hal.)	4-Sep	bycatch (hal.)	
	8-Sep	open	8-Sep	open	8-Sep	open	
	10-Sep	bycatch (hal.)	10-Sep	bycatch (hal.)	10-Sep	bycatch (hal.)	
	1-Oct	open	1-Oct	open	1-Oct	open	
	1-Oct	bycatch (hal.)	1-Oct	bycatch (hal.)	1-Oct	bycatch (hal.)	

Table 4a.4. Annual fishery length compositions for Dover sole, 1991-2004. As of Sept. 30, 2005, the 2005 fishery size composition was unavailable.

a) Females.

	Length cutpoints																								
year	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50	52	54	56	58	60	62	64	66
1991	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0009	0.0009	0.0037	0.0232	0.0639	0.0899	0.0732	0.0741	0.0380	0.0269	0.0083	0.0065	0.0009	0.0000	0.0000	0.0000	0.0000	0.0000
1992	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0136	0.0245	0.0326	0.0435	0.0788	0.0815	0.0951	0.0516	0.0516	0.0245	0.0136	0.0163	0.0082	0.0000	0.0000	0.0000
1993	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0014	0.0151	0.0475	0.0523	0.0571	0.0440	0.0536	0.0530	0.0337	0.0213	0.0220	0.0117	0.0076	0.0089	0.0014	0.0034	0.0000	0.0000
1994	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0011	0.0028	0.0084	0.0230	0.0342	0.0521	0.0498	0.0398	0.0146	0.0101	0.0017	0.0022	0.0017	0.0006	0.0006	0.0000	0.0000
1995	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0020	0.0014	0.0055	0.0212	0.0519	0.0710	0.0874	0.0689	0.0246	0.0300	0.0048	0.0082	0.0041	0.0007	0.0007	0.0000	0.0000	0.0000
1996	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0035	0.0141	0.0281	0.0295	0.0436	0.0949	0.0984	0.0970	0.0548	0.0323	0.0119	0.0035	0.0000	0.0000	0.0014	0.0000	0.0000
1997	0.0000	0.0000	0.0000	0.0000	0.0000	0.0004	0.0000	0.0000	0.0017	0.0043	0.0189	0.0262	0.0404	0.0593	0.0641	0.0567	0.0340	0.0301	0.0155	0.0107	0.0052	0.0030	0.0009	0.0004	0.0004
1998	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0019	0.0034	0.0083	0.0131	0.0224	0.0423	0.0734	0.0987	0.0705	0.0423	0.0292	0.0088	0.0039	0.0010	0.0005	0.0000	0.0000
1999	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0008	0.0033	0.0098	0.0139	0.0336	0.0443	0.0541	0.0607	0.0541	0.0754	0.0639	0.0402	0.0172	0.0148	0.0098	0.0057	0.0057	0.0016	0.0033
2000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0012	0.0012	0.0012	0.0036	0.0061	0.0109	0.0133	0.0376	0.0533	0.0836	0.0703	0.0339	0.0424	0.0170	0.0073	0.0036	0.0012	0.0000	0.0000
2001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0014	0.0014	0.0112	0.0238	0.0266	0.0266	0.0281	0.0505	0.0631	0.0477	0.0533	0.0309	0.0168	0.0056	0.0028	0.0028	0.0000
2002	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0036	0.0000	0.0000	0.0072	0.0000	0.0108	0.0072	0.0253	0.0108	0.0578	0.0505	0.0289	0.0289	0.0108	0.0000	0.0000	0.0072	0.0000
2003	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0024	0.0000	0.0024	0.0048	0.0048	0.0217	0.0217	0.0193	0.0217	0.0410	0.0723	0.0482	0.0337	0.0241	0.0096	0.0048	0.0048	0.0000	0.0000
2004	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0016	0.0000	0.0000	0.0080	0.0112	0.0128	0.0256	0.0416	0.0400	0.0512	0.0608	0.0384	0.0224	0.0192	0.0256	0.0032	0.0048	0.0016

b) Males.

	Length cutpoints																								
year	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50	52	54	56	58	60	62	64	66
1991	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0065	0.0074	0.0352	0.0639	0.1084	0.1705	0.1010	0.0547	0.0278	0.0120	0.0019	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1992	0.0000	0.0000	0.0000	0.0000	0.0000	0.0027	0.0027	0.0163	0.0054	0.0299	0.0897	0.0734	0.0870	0.0870	0.0326	0.0190	0.0109	0.0027	0.0054	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1993	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0041	0.0715	0.1534	0.1355	0.0805	0.0426	0.0296	0.0131	0.0186	0.0069	0.0028	0.0021	0.0034	0.0014	0.0000	0.0000	0.0000	0.0000
1994	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0006	0.0050	0.0672	0.1837	0.2032	0.1355	0.0773	0.0476	0.0140	0.0179	0.0056	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1995	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0007	0.0007	0.0273	0.1092	0.1768	0.1222	0.0935	0.0491	0.0280	0.0068	0.0007	0.0014	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1996	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0021	0.0260	0.0892	0.0907	0.1103	0.0921	0.0457	0.0176	0.0063	0.0042	0.0007	0.0007	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000
1997	0.0000	0.0000	0.0000	0.0000	0.0000	0.0004	0.0004	0.0026	0.0249	0.0791	0.1113	0.1079	0.1101	0.0864	0.0623	0.0331	0.0064	0.0013	0.0009	0.0000	0.0000	0.0004	0.0000	0.0000	0.0000
1998	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0024	0.0209	0.0482	0.0997	0.1167	0.1269	0.0958	0.0409	0.0195	0.0049	0.0019	0.0010	0.0000	0.0000	0.0000	0.0010	0.0005	0.0000
1999	0.0000	0.0000	0.0008	0.0000	0.0008	0.0016	0.0033	0.0082	0.0262	0.0475	0.0811	0.0713	0.0803	0.0639	0.0590	0.0262	0.0098	0.0041	0.0016	0.0008	0.0000	0.0000	0.0000	0.0008	0.0000
2000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0012	0.0012	0.0012	0.0048	0.0327	0.0885	0.1297	0.1152	0.1067	0.0715	0.0339	0.0158	0.0036	0.0036	0.0012	0.0012	0.0000	0.0000	0.0000	0.0000
2001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0014	0.0014	0.0056	0.0084	0.0379	0.0996	0.1360	0.0912	0.0982	0.0645	0.0281	0.0168	0.0070	0.0070	0.0014	0.0028	0.0000	0.0000	0.0000
2002	0.0000	0.0000	0.0000	0.0000	0.0036	0.0000	0.0000	0.0072	0.0036	0.0000	0.0217	0.1119	0.1083	0.1444	0.1588	0.0975	0.0397	0.0397	0.0108	0.0036	0.0000	0.0000	0.0000	0.0000	0.0000
2003	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0072	0.0120	0.0627	0.1205	0.1133	0.1157	0.0795	0.0940	0.0361	0.0072	0.0072	0.0024	0.0048	0.0000	0.0000	0.0000	0.0000	0.0000
2004	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0016	0.0000	0.0000	0.0224	0.0704	0.0688	0.0816	0.1232	0.1296	0.0848	0.0288	0.0080	0.0112	0.0016	0.0000	0.0000	0.0000	0.0000	0.0000

Table 4a.5. Sample sizes: a) sample sizes for length compositions from the domestic fishery and b) sample sizes for estimated biomass, age and size compositions from the GOA groundfish survey.

a). Fishery length compositions. Length compositions were not created for 1990 or 2005.

year	# Individuals	# Hauls
1990	249	2
1991	1079	20
1992	368	11
1993	1454	27
1994	1786	26
1995	1465	23
1996	1423	23
1997	2326	41
1998	2056	48
1999	1220	62
2000	899	48
2001	713	44
2002	277	15
2003	415	27
2004	625	33
2005	12	2

b). GOA groundfish surveys.

	Biomass	Age Samples		Length Samples	
year	# Hauls	# Individuals	# Hauls	# Individuals	# Hauls
1984	929	464	13	10147	217
1987	783			5230	84
1990	708			7435	195
1993	775	252	35	10275	320
1996	807	383	66	7206	414
1999	764	353	65	6926	388
2001	489	543	131	1960	187
2003	809			6741	394
2005	839			7272	440

Table 4a.6. Biomass estimates and standard errors from NMFS bottom trawl surveys. Survey depth coverage represents the maximum depth surveyed. In 2001, the eastern GOA was not surveyed, nor were strata > 500 m depth. Availability is the estimated fraction of total biomass covered in a survey (Turnock et al, 2003). Corrected biomass scales survey biomass to standard area.

year	Survey Biomass (t)	Std. Error	Availability	Corrected Biomass (t)	Survey Depth Coverage
1984	68,521	6,136	1	68,521	1-1000 m
1987	63,394	7,388	1	63,394	1-1000 m
1990	96,597	12,375	0.82	117,801	1-500 m
1993	85,549	6,441	0.82	104,329	1-500 m
1996	79,531	5,624	0.82	96,989	1-500 m
1999	74,245	5,236	1	74,245	1-1000 m
2001	32,424	3,758	0.42	77,200	1-500 m
2003	99,297	10,544	1	99,297	1-700 m
2005	80,537	6,794	1	80,537	1-1000 m

Table 4a.7. Survey biomass estimates (t) by depth strata for each survey year.

	Depth range					
year	1-100	101-200	201-300	301-500	501-700	701-1000
1984	2,829	30,220	7,928	6,822	8,166	12,557
1987	4,401	25,831	12,039	8,934	10,542	1,647
1990	12,290	57,774	19,985	6,549		
1993	4,760	43,999	19,930	16,861		
1996	6,561	37,856	18,101	17,013		
1999	6,431	28,549	19,576	12,317	6,049	1,323
2001	3,803	16,294	7,491	4,836		
2003	10,154	45,181	17,832	13,593	12,537	
2005	6,654	32,613	17,674	17,774	3,134	2,689

Table 4a.8. Survey biomass by area. In 2003, the survey was not conducted in the Yakutat and Southeastern areas. Shading denotes surveys with full depth coverage (1-1000 m).

	Survey area				
year	Shumagin	Chirikof	Kodiak	Yakutat	Southeastern
1984	4,460	15,502	36,967	7,516	4,076
1987	2,623	16,500	18,077	21,067	5,127
1990	1,649	26,113	44,996	18,699	5,140
1993	2,371	13,244	30,271	26,877	12,787
1996	1,458	12,429	24,715	29,766	11,162
1999	1,442	9,716	24,439	25,647	13,001
2001	895	13,850	17,679		
2003	3,149	15,882	33,401	31,609	15,256
2005	2,832	12,358	26,524	25,177	13,646

Table 4a.9. Survey age compositions for Dover sole.

a) Females.

year	Age Bins 3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	25	30	35	40
1993	175,468	589,597	1,987,286	1,334,975	1,500,052	897,501	1,883,943	2,547,864	2,467,711	2,367,420	2,738,483	3,073,772	2,300,861	63,879	1,204,741	1,307,452	140,334	5,952,348	7,116,675	6,941,040	2,988,844	420,415
1996	306,730	500,830	2,116,609	506,687	543,968	1,224,424	2,313,215	643,320	1,853,676	2,663,814	2,178,534	751,068	2,755,962	1,695,299	1,228,467	1,091,717	1,665,235	8,557,422	4,226,370	4,169,151	2,463,610	1,966,931
1999	114,907	1,052,940	3,131,470	1,609,283	750,687	1,085,458	1,384,174	524,448	1,591,697	762,811	1,816,584	992,802	2,729,421	2,762,499	1,186,373	852,452	853,313	5,355,809	3,374,473	3,159,376	1,496,633	4,462,199
2001	162,773	631,557	1,053,997	1,096,961	676,309	779,114	125,722	369,652	0	0	175,367	182,634	457,045	0	877,147	685,463	180,299	1,568,113	1,822,027	2,281,102	2,052,032	949,628

b) Males.

year	Age Bins 3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	25	30	35	40
1993	1,547,990	2,407,719	4,087,338	2,708,632	4,725,480	5,211,767	2,819,716	3,362,262	1,104,988	2,325,228	1,318,480	1,149,482	2,193,285	1,167,653	968,468	663,149	595,469	6,226,585	1,703,156	1,868,705	1,631,736	0
1996	275,501	1,125,039	3,362,010	2,317,514	2,125,828	2,167,404	2,813,505	1,522,745	1,380,784	4,437,499	5,055,895	3,899,908	2,832,262	2,450,190	629,467	1,551,937	1,792,496	4,054,522	2,601,717	0	752,381	324,873
1999	550,609	2,912,338	3,421,018	2,455,500	806,259	2,020,493	876,111	749,541	1,020,575	1,239,225	534,099	1,447,501	75,987	1,388,766	624,807	2,539,544	75,987	9,438,144	5,527,949	4,911,877	6,258,749	6,020,747
2001	352,700	1,015,131	1,538,281	1,792,614	1,624,724	765,731	337,948	456,200	378,793	104,682	0	280,038	0	593,322	228,101	0	528,946	1,773,053	1,490,781	1,764,407	1,756,096	201,249

Table 4a.10. Survey length compositions for Dover sole. Survey length compositions from 1993, 1996, 1999 and 2001 were not included in the assessment because age compositions were available for these years.

a) Females.

year	length cutpoints (cm) 18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50	52	54	56	58	60	62	64	66
1984	0	0	0	57,202	102,501	769,663	1,380,492	2,521,239	3,523,128	4,471,698	5,530,032	6,600,259	5,515,142	4,126,363	3,204,886	2,297,298	1,616,048	917,909	697,263	184,003	158,947	52,658	36,393	0	0
1987	0	45,016	235,938	68,955	148,167	307,091	495,005	1,026,637	1,906,843	2,767,360	4,771,983	6,097,976	6,139,135	6,027,697	4,393,082	3,057,823	1,740,018	1,376,400	523,549	278,789	202,238	0	0	0	0
1990	22,956	22,956	22,956	13,598	41,030	172,944	499,540	808,258	1,177,712	2,346,800	3,233,110	5,506,590	7,594,986	10,100,104	8,524,664	7,073,956	6,797,642	2,907,377	1,249,981	845,502	218,833	69,827	129,991	1,992	0
1993	0	0	11,462	73,326	182,567	246,836	649,643	968,351	1,386,912	1,677,424	2,257,020	3,460,390	5,314,430	6,986,581	8,763,514	6,453,435	5,151,420	3,306,737	1,561,756	999,627	530,696	211,274	87,786	36,040	17,527
1996	92,571	113,077	185,170	300,308	323,831	398,536	521,471	988,802	1,620,893	1,730,806	2,234,114	2,358,219	3,288,388	4,434,603	5,755,202	6,347,051	5,787,072	4,286,438	2,545,825	1,484,355	616,114	257,003	85,136	55,291	0
1999	52,602	132,643	154,499	390,048	613,774	1,361,976	1,878,144	1,437,027	1,803,891	2,043,884	2,296,925	2,770,592	3,315,793	3,514,190	4,080,084	4,118,160	4,774,577	3,327,383	2,138,709	1,283,917	627,980	103,625	41,671	0	0
2001	102,334	73,284	59,013	47,188	236,182	416,309	339,989	380,733	602,693	756,547	653,491	501,433	505,055	784,857	1,117,015	1,589,017	1,583,603	1,870,498	1,716,510	953,575	842,735	739,512	253,740	232,479	99,465
2003	2,261,885	1,400,656	1,701,836	1,415,951	1,551,539	2,242,012	2,755,763	2,283,068	2,536,021	4,030,631	3,668,423	3,983,149	4,001,807	4,705,435	4,302,217	3,893,327	4,461,349	3,477,964	2,885,181	1,806,430	1,032,076	368,932	169,269	114,878	11,639
2005	133,156	161,877	578,168	724,276	908,254	1,856,447	2,413,181	2,591,692	3,675,633	3,828,497	3,337,648	3,709,138	3,238,401	3,031,786	3,193,373	2,884,642	2,682,000	2,824,069	2,295,295	1,748,419	1,320,980	328,535	237,267	78,913	7,473

b) Males.

year	length cutpoints (cm) 18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50	52	54	56	58	60	62	64	66
1984	0	0	42,430	299,982	814,541	1,976,631	3,423,512	7,462,439	13,139,517	13,922,994	9,557,996	5,446,004	2,543,129	1,309,705	428,973	120,474	71,279	142,775	9,682	101,827	0	0	48,493	0	0
1987	0	0	84,329	73,215	303,164	940,394	1,354,051	2,591,737	6,251,352	8,145,509	9,794,006	7,360,218	4,082,985	1,996,811	876,374	430,311	222,466	0	14,051	0	0	0	0	0	0
1990	0	36,985	19,778	42,055	80,222	618,773	917,417	2,263,527	3,832,151	6,827,860	10,361,043	11,751,959	9,519,127	3,740,645	1,410,069	787,375	694,727	325,617	48,987	0	0	0	0	0	0
1993	12,727	36,120	50,185	141,174	200,232	604,950	993,589	1,821,622	4,317,299	6,812,913	9,588,183	10,428,053	7,948,676	4,588,644	1,883,785	920,912	333,622	97,058	66,519	0	20,925	0	0	0	0
1996	24,545	139,728	132,438	325,907	451,555	514,483	1,285,591	2,238,981	3,871,480	6,314,176	8,310,170	9,525,589	7,492,764	4,118,991	1,842,068	674,100	308,558	90,639	22,864	5,269	0	0	0	0	0
1999	90,008	17,651	504,103	840,654	1,265,914	1,964,539	2,607,586	3,365,297	3,774,481	5,707,034	8,411,190	9,447,302	7,077,466	5,435,287	3,222,530	1,217,084	559,618	205,268	26,392	24,250	0	0	0	0	0
2001	48,786	26,071	70,977	111,014	232,397	563,938	879,434	924,153	1,423,912	896,113	1,720,798	2,705,109	2,832,590	2,084,216	1,381,550	531,051	353,326	182,903	67,297	0	0	0	0	0	17,191
2003	1,658,710	1,430,699	2,125,764	2,007,904	2,682,376	3,400,040	3,539,995	3,972,778	4,961,407	5,980,065	9,086,379	10,931,231	10,659,896	8,671,309	5,368,529	2,966,019	1,568,606	417,111	64,530	65,000	0	27,916	0	0	0
2005	90,948	275,573	656,016	936,960	1,407,411	2,016,909	2,875,520	4,358,413	5,636,146	6,546,388	8,028,912	8,128,357	7,493,406	6,183,898	3,405,760	1,966,610	1,022,764	217,832	104,822	11,924	0	0	0	0	0

Table 4a.11a. Age-length transition matrices for female Dover sole. Values at a row/column combination correspond to the fraction of individuals at the age indicated by the row that fall into the length group indicated by the column.

	length cutpts (cm)																								
age	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50	52	54	56	58	60	62	64	66
3	0.0265	0.0654	0.143	0.2188	0.2343	0.1756	0.0922	0.0338	0.0087	0.0016	0.0002	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0.0053	0.017	0.0493	0.1074	0.175	0.2135	0.1951	0.1335	0.0683	0.0262	0.0075	0.0016	0.0003	0	0	0	0	0	0	0	0	0	0	0	0
5	0.0013	0.0048	0.0165	0.0439	0.0915	0.1495	0.1913	0.1915	0.1502	0.0922	0.0443	0.0167	0.0049	0.0011	0.0002	0	0	0	0	0	0	0	0	0	0
6	0.0004	0.0016	0.006	0.0181	0.0439	0.0863	0.137	0.1757	0.1821	0.1524	0.1031	0.0563	0.0249	0.0089	0.0026	0.0006	0.0001	0	0	0	0	0	0	0	0
7	0.0002	0.0006	0.0025	0.008	0.0215	0.0477	0.0874	0.1327	0.1664	0.1725	0.1478	0.1047	0.0613	0.0297	0.0119	0.0039	0.0011	0.0002	0	0	0	0	0	0	0
8	0.0001	0.0003	0.0011	0.0039	0.0111	0.0268	0.0544	0.0929	0.1334	0.161	0.1636	0.1397	0.1004	0.0607	0.0308	0.0132	0.0047	0.0014	0.0004	0.0001	0	0	0	0	0
9	0	0.0001	0.0006	0.002	0.0062	0.0158	0.0344	0.0639	0.1013	0.1368	0.1576	0.1547	0.1294	0.0923	0.0561	0.0291	0.0128	0.0048	0.0016	0.0004	0.0001	0	0	0	0
10	0	0.0001	0.0003	0.0012	0.0037	0.0098	0.0224	0.0444	0.0758	0.1115	0.1412	0.154	0.1447	0.1171	0.0817	0.0491	0.0254	0.0113	0.0043	0.0014	0.0004	0.0001	0	0	0
11	0	0	0.0002	0.0007	0.0023	0.0064	0.0152	0.0317	0.0572	0.0896	0.1222	0.1446	0.1487	0.1329	0.1031	0.0695	0.0407	0.0207	0.0092	0.0035	0.0012	0.0003	0.0001	0	0
12	0	0	0.0001	0.0005	0.0015	0.0044	0.0108	0.0232	0.0438	0.0723	0.1043	0.1317	0.1454	0.1405	0.1187	0.0877	0.0567	0.0321	0.0159	0.0069	0.0026	0.0009	0.0002	0.0001	0
13	0	0	0.0001	0.0003	0.0011	0.0031	0.0079	0.0175	0.0343	0.0588	0.0889	0.1182	0.1382	0.1421	0.1286	0.1023	0.0716	0.0441	0.0239	0.0114	0.0048	0.0018	0.0006	0.0002	0.0001
14	0	0	0.0001	0.0002	0.0008	0.0023	0.006	0.0137	0.0274	0.0486	0.0763	0.1057	0.1294	0.1401	0.134	0.1133	0.0846	0.0559	0.0326	0.0168	0.0077	0.0031	0.0011	0.0003	0.0001
15	0	0	0	0.0002	0.0006	0.0018	0.0047	0.0109	0.0224	0.0408	0.066	0.0946	0.1204	0.1359	0.136	0.1209	0.0953	0.0666	0.0413	0.0228	0.0111	0.0048	0.0019	0.0006	0.0003
16	0	0	0	0.0001	0.0005	0.0014	0.0038	0.009	0.0187	0.0349	0.0578	0.0852	0.1118	0.1306	0.1359	0.1258	0.1037	0.0761	0.0497	0.0289	0.0149	0.0069	0.0028	0.001	0.0005
17	0	0	0	0.0001	0.0004	0.0012	0.0032	0.0075	0.016	0.0302	0.0511	0.0772	0.104	0.1251	0.1343	0.1287	0.1101	0.0841	0.0573	0.0349	0.0189	0.0092	0.004	0.0015	0.0008
18	0	0	0	0.0001	0.0003	0.001	0.0027	0.0064	0.0138	0.0266	0.0458	0.0705	0.0971	0.1197	0.132	0.1302	0.115	0.0908	0.0642	0.0406	0.023	0.0116	0.0053	0.0021	0.0011
19	0	0	0	0.0001	0.0003	0.0009	0.0023	0.0056	0.0122	0.0238	0.0415	0.0649	0.0911	0.1146	0.1292	0.1307	0.1185	0.0963	0.0702	0.0459	0.0269	0.0141	0.0066	0.0028	0.0016
20	0	0	0	0.0001	0.0002	0.0008	0.002	0.005	0.0109	0.0215	0.0379	0.0602	0.0858	0.1099	0.1263	0.1305	0.121	0.1008	0.0754	0.0507	0.0306	0.0166	0.0081	0.0035	0.0021
21	0	0	0	0.0001	0.0002	0.0007	0.0018	0.0045	0.0099	0.0196	0.0351	0.0563	0.0813	0.1057	0.1235	0.1298	0.1228	0.1044	0.0799	0.055	0.034	0.019	0.0095	0.0043	0.0027
22	0	0	0	0.0001	0.0002	0.0006	0.0017	0.0041	0.0091	0.0181	0.0327	0.053	0.0774	0.1019	0.1208	0.1289	0.124	0.1074	0.0837	0.0588	0.0372	0.0212	0.0109	0.005	0.0033
23	0	0	0	0.0001	0.0002	0.0006	0.0015	0.0038	0.0084	0.0169	0.0307	0.0502	0.0741	0.0985	0.1182	0.1279	0.1248	0.1097	0.087	0.0622	0.0401	0.0233	0.0122	0.0058	0.0039
24	0	0	0	0	0.0002	0.0005	0.0014	0.0035	0.0078	0.0159	0.029	0.0478	0.0712	0.0956	0.1159	0.1268	0.1252	0.1116	0.0898	0.0652	0.0427	0.0253	0.0135	0.0065	0.0045
25	0	0	0	0	0.0002	0.0005	0.0013	0.0033	0.0074	0.015	0.0276	0.0458	0.0687	0.093	0.1138	0.1257	0.1255	0.1132	0.0922	0.0678	0.0451	0.0271	0.0147	0.0072	0.0051
26	0	0	0	0	0.0001	0.0004	0.0012	0.0031	0.007	0.0143	0.0264	0.0441	0.0665	0.0907	0.1118	0.1247	0.1256	0.1144	0.0942	0.0701	0.0472	0.0287	0.0158	0.0078	0.0057
27	0	0	0	0	0.0001	0.0004	0.0012	0.003	0.0067	0.0137	0.0254	0.0426	0.0646	0.0887	0.1101	0.1236	0.1256	0.1154	0.0959	0.0721	0.049	0.0302	0.0168	0.0084	0.0063
28	0	0	0	0	0.0001	0.0004	0.0011	0.0028	0.0064	0.0132	0.0246	0.0413	0.063	0.087	0.1086	0.1227	0.1255	0.1162	0.0974	0.0738	0.0507	0.0315	0.0177	0.009	0.0069
29	0	0	0	0	0.0001	0.0004	0.0011	0.0027	0.0062	0.0128	0.0238	0.0403	0.0616	0.0854	0.1072	0.1218	0.1254	0.1169	0.0986	0.0754	0.0522	0.0327	0.0185	0.0095	0.0074
30	0	0	0	0	0.0001	0.0004	0.001	0.0026	0.006	0.0124	0.0232	0.0393	0.0604	0.0841	0.106	0.1211	0.1253	0.1174	0.0997	0.0767	0.0534	0.0337	0.0193	0.01	0.0078
31	0	0	0	0	0.0001	0.0004	0.001	0.0026	0.0058	0.0121	0.0226	0.0385	0.0593	0.0829	0.1049	0.1203	0.1251	0.1178	0.1006	0.0779	0.0546	0.0347	0.02	0.0104	0.0083
32	0	0	0	0	0.0001	0.0004	0.001	0.0025	0.0057	0.0118	0.0222	0.0378	0.0584	0.0818	0.104	0.1197	0.1249	0.1182	0.1014	0.0789	0.0556	0.0355	0.0206	0.0108	0.0087
33	0	0	0	0	0.0001	0.0003	0.001	0.0024	0.0056	0.0116	0.0218	0.0372	0.0576	0.0809	0.1031	0.1191	0.1248	0.1185	0.1021	0.0797	0.0565	0.0363	0.0211	0.0112	0.0091
34	0	0	0	0	0.0001	0.0003	0.0009	0.0024	0.0055	0.0114	0.0214	0.0367	0.0569	0.0801	0.1024	0.1186	0.1246	0.1188	0.1027	0.0805	0.0573	0.037	0.0216	0.0115	0.0094
35	0	0	0	0	0.0001	0.0003	0.0009	0.0023	0.0054	0.0112	0.0211	0.0362	0.0563	0.0794	0.1017	0.1181	0.1245	0.119	0.1032	0.0812	0.058	0.0375	0.0221	0.0118	0.0097
36	0	0	0	0	0.0001	0.0003	0.0009	0.0023	0.0053	0.011	0.0208	0.0358	0.0558	0.0788	0.1011	0.1177	0.1243	0.1192	0.1036	0.0818	0.0586	0.0381	0.0224	0.012	0.01
37	0	0	0	0	0.0001	0.0003	0.0009	0.0023	0.0052	0.0109	0.0206	0.0354	0.0553	0.0783	0.1006	0.1173	0.1242	0.1193	0.104	0.0823	0.0591	0.0385	0.0228	0.0122	0.0102
38	0	0	0	0	0.0001	0.0003	0.0009	0.0022	0.0052	0.0108	0.0204	0.0351	0.0549	0.0778	0.1001	0.117	0.1241	0.1194	0.1044	0.0828	0.0596	0.0389	0.0231	0.0124	0.0104
39	0	0	0	0	0.0001	0.0003	0.0009	0.0022	0.0051	0.0107	0.0202	0.0349	0.0545	0.0774	0.0997	0.1167	0.124	0.1195	0.1046	0.0832	0.06	0.0393	0.0234	0.0126	0.0106
40	0	0	0	0	0.0001	0.0003	0.0009	0.0022	0.0051	0.0106	0.0201	0.0346	0.0542	0.077	0.0994	0.1164	0.1239	0.1196	0.1049	0.0835	0.0604	0.0396	0.0236	0.0128	0.0108

Table 4a.11b. Age-length transition matrices for male Dover sole. Values at a row/column combination correspond to the fraction of individuals at the age indicated by the row that fall into the length group indicated by the column.

	length cutpts (cm)																								
age	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50	52	54	56	58	60	62	64	66
3	0.0296	0.0688	0.1453	0.2171	0.2298	0.1723	0.0915	0.0344	0.0092	0.0017	0.0002	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0.0063	0.0192	0.0541	0.1141	0.1804	0.2139	0.19	0.1266	0.0632	0.0237	0.0066	0.0014	0.0002	0	0	0	0	0	0	0	0	0	0	0	0
5	0.0017	0.0061	0.0202	0.0523	0.105	0.1639	0.1988	0.1872	0.137	0.0778	0.0343	0.0118	0.0031	0.0006	0.0001	0	0	0	0	0	0	0	0	0	0
6	0.0006	0.0022	0.0083	0.0246	0.0578	0.1081	0.1608	0.19	0.1785	0.1333	0.0791	0.0373	0.014	0.0042	0.001	0.0002	0	0	0	0	0	0	0	0	0
7	0.0002	0.0009	0.0038	0.0124	0.0327	0.0695	0.1192	0.165	0.1845	0.1665	0.1214	0.0715	0.034	0.013	0.004	0.001	0.0002	0	0	0	0	0	0	0	0
8	0.0001	0.0005	0.0019	0.0068	0.0195	0.0456	0.0869	0.1352	0.1717	0.1779	0.1505	0.1038	0.0585	0.0269	0.0101	0.0031	0.0008	0.0002	0	0	0	0	0	0	0
9	0.0001	0.0002	0.0011	0.004	0.0123	0.031	0.0642	0.1093	0.1529	0.1758	0.1662	0.1291	0.0825	0.0433	0.0187	0.0066	0.0019	0.0005	0.0001	0	0	0	0	0	0
10	0	0.0001	0.0006	0.0025	0.0082	0.022	0.0487	0.0889	0.1342	0.1674	0.1724	0.1467	0.1031	0.0599	0.0287	0.0114	0.0037	0.001	0.0002	0	0	0	0	0	0
11	0	0.0001	0.0004	0.0017	0.0057	0.0162	0.0379	0.0734	0.1179	0.1569	0.173	0.1581	0.1196	0.075	0.039	0.0168	0.006	0.0018	0.0004	0.0001	0	0	0	0	0
12	0	0.0001	0.0003	0.0012	0.0042	0.0123	0.0302	0.0617	0.1044	0.1465	0.1707	0.165	0.1324	0.0881	0.0487	0.0223	0.0085	0.0027	0.0007	0.0002	0	0	0	0	0
13	0	0	0.0002	0.0008	0.0031	0.0096	0.0247	0.0527	0.0933	0.137	0.1671	0.1691	0.1421	0.0991	0.0574	0.0276	0.011	0.0036	0.001	0.0002	0	0	0	0	0
14	0	0	0.0001	0.0006	0.0024	0.0077	0.0207	0.0458	0.0843	0.1287	0.1631	0.1715	0.1496	0.1083	0.065	0.0324	0.0134	0.0046	0.0013	0.0003	0.0001	0	0	0	0
15	0	0	0.0001	0.0005	0.0019	0.0063	0.0176	0.0404	0.077	0.1216	0.1592	0.1728	0.1554	0.1158	0.0716	0.0366	0.0156	0.0055	0.0016	0.0004	0.0001	0	0	0	0
16	0	0	0.0001	0.0004	0.0015	0.0053	0.0152	0.0361	0.071	0.1156	0.1557	0.1736	0.1601	0.1221	0.0771	0.0403	0.0174	0.0062	0.0018	0.0004	0.0001	0	0	0	0
17	0	0	0.0001	0.0003	0.0012	0.0045	0.0133	0.0326	0.066	0.1105	0.1527	0.1742	0.164	0.1274	0.0817	0.0433	0.0189	0.0068	0.002	0.0005	0.0001	0	0	0	0
18	0	0	0	0.0002	0.001	0.0038	0.0117	0.0296	0.0619	0.1062	0.1501	0.1747	0.1673	0.1319	0.0856	0.0457	0.0201	0.0073	0.0022	0.0005	0.0001	0	0	0	0
19	0	0	0	0.0002	0.0008	0.0033	0.0104	0.0272	0.0583	0.1025	0.148	0.1752	0.1703	0.1358	0.0888	0.0477	0.021	0.0076	0.0022	0.0005	0.0001	0	0	0	0
20	0	0	0	0.0001	0.0007	0.0028	0.0093	0.0251	0.0552	0.0994	0.1462	0.1759	0.173	0.1391	0.0915	0.0492	0.0216	0.0078	0.0023	0.0005	0.0001	0	0	0	0
21	0	0	0	0.0001	0.0006	0.0025	0.0084	0.0233	0.0526	0.0967	0.1448	0.1767	0.1756	0.1421	0.0937	0.0503	0.022	0.0078	0.0023	0.0005	0.0001	0	0	0	0
22	0	0	0	0.0001	0.0005	0.0021	0.0076	0.0217	0.0502	0.0943	0.1437	0.1776	0.1781	0.1448	0.0955	0.0511	0.0222	0.0078	0.0022	0.0005	0.0001	0	0	0	0
23	0	0	0	0.0001	0.0004	0.0019	0.0069	0.0202	0.048	0.0922	0.1428	0.1787	0.1805	0.1472	0.097	0.0515	0.0221	0.0077	0.0021	0.0005	0.0001	0	0	0	0
24	0	0	0	0.0001	0.0003	0.0016	0.0062	0.0189	0.0461	0.0903	0.1422	0.1799	0.183	0.1495	0.0981	0.0518	0.0219	0.0075	0.002	0.0004	0.0001	0	0	0	0
25	0	0	0	0	0.0003	0.0014	0.0056	0.0177	0.0443	0.0886	0.1417	0.1813	0.1854	0.1516	0.0991	0.0518	0.0216	0.0072	0.0019	0.0004	0.0001	0	0	0	0
26	0	0	0	0	0.0002	0.0013	0.0051	0.0166	0.0426	0.087	0.1414	0.1828	0.1878	0.1535	0.0998	0.0516	0.0212	0.0069	0.0018	0.0004	0.0001	0	0	0	0
27	0	0	0	0	0.0002	0.0011	0.0046	0.0155	0.041	0.0855	0.1412	0.1844	0.1903	0.1554	0.1003	0.0512	0.0206	0.0066	0.0017	0.0003	0.0001	0	0	0	0
28	0	0	0	0	0.0002	0.001	0.0042	0.0145	0.0394	0.0841	0.1411	0.1861	0.1929	0.1571	0.1006	0.0506	0.02	0.0062	0.0015	0.0003	0	0	0	0	0
29	0	0	0	0	0.0001	0.0008	0.0038	0.0136	0.0379	0.0828	0.1411	0.1879	0.1955	0.1588	0.1008	0.05	0.0194	0.0059	0.0014	0.0003	0	0	0	0	0
30	0	0	0	0	0.0001	0.0007	0.0034	0.0127	0.0365	0.0815	0.1411	0.1898	0.1981	0.1604	0.1009	0.0492	0.0186	0.0055	0.0012	0.0002	0	0	0	0	0
31	0	0	0	0	0.0001	0.0006	0.0031	0.0118	0.0351	0.0801	0.1412	0.1918	0.2008	0.162	0.1008	0.0483	0.0178	0.0051	0.0011	0.0002	0	0	0	0	0
32	0	0	0	0	0.0001	0.0005	0.0027	0.011	0.0337	0.0788	0.1413	0.1939	0.2035	0.1636	0.1006	0.0473	0.017	0.0047	0.001	0.0002	0	0	0	0	0
33	0	0	0	0	0.0001	0.0004	0.0025	0.0102	0.0323	0.0775	0.1415	0.196	0.2064	0.165	0.1003	0.0463	0.0162	0.0043	0.0009	0.0001	0	0	0	0	0
34	0	0	0	0	0	0.0004	0.0022	0.0094	0.0309	0.0762	0.1416	0.1983	0.2093	0.1665	0.0998	0.0451	0.0154	0.0039	0.0008	0.0001	0	0	0	0	0
35	0	0	0	0	0	0.0003	0.0019	0.0087	0.0296	0.0749	0.1417	0.2006	0.2123	0.1679	0.0993	0.0439	0.0145	0.0036	0.0007	0.0001	0	0	0	0	0
36	0	0	0	0	0	0.0003	0.0017	0.008	0.0282	0.0735	0.1418	0.203	0.2153	0.1693	0.0987	0.0426	0.0137	0.0032	0.0006	0.0001	0	0	0	0	0
37	0	0	0	0	0	0.0002	0.0015	0.0074	0.0269	0.072	0.1419	0.2054	0.2185	0.1707	0.098	0.0413	0.0128	0.0029	0.0005	0.0001	0	0	0	0	0
38	0	0	0	0	0	0.0002	0.0013	0.0067	0.0255	0.0706	0.142	0.2079	0.2217	0.172	0.0972	0.0399	0.0119	0.0026	0.0004	0	0	0	0	0	0
39	0	0	0	0	0	0.0001	0.0011	0.0061	0.0242	0.069	0.142	0.2105	0.225	0.1733	0.0962	0.0385	0.0111	0.0023	0.0003	0	0	0	0	0	0
40	0	0	0	0	0	0.0001	0.001	0.0055	0.0229	0.0674	0.142	0.2132	0.2284	0.1746	0.0952	0.037	0.0103	0.002	0.0003	0	0	0	0	0	0

Table 4a.12. Weight-at-age and maturity-at-age for Dover sole in the Gulf of Alaska.

age	weight at age (kg) female	male	maturity-at-age
3	0.16	0.16	0.000
4	0.21	0.22	0.000
5	0.32	0.31	0.001
6	0.42	0.38	0.003
7	0.51	0.44	0.009
8	0.60	0.49	0.028
9	0.68	0.53	0.072
10	0.75	0.57	0.156
11	0.82	0.61	0.283
12	0.88	0.63	0.437
13	0.94	0.66	0.584
14	0.99	0.68	0.703
15	1.04	0.70	0.789
16	1.08	0.71	0.849
17	1.12	0.72	0.889
18	1.16	0.74	0.917
19	1.19	0.74	0.935
20	1.23	0.75	0.949
21	1.25	0.76	0.958
22	1.28	0.77	0.965
23	1.31	0.77	0.970
24	1.33	0.78	0.974
25	1.35	0.78	0.977
26	1.37	0.78	0.980
27	1.39	0.79	0.982
28	1.40	0.79	0.983
29	1.42	0.79	0.984
30	1.43	0.79	0.985
31	1.44	0.79	0.986
32	1.46	0.79	0.987
33	1.47	0.80	0.988
34	1.48	0.80	0.988
35	1.49	0.80	0.989
36	1.49	0.80	0.989
37	1.50	0.80	0.989
38	1.51	0.80	0.989
39	1.51	0.80	0.990
40	1.52	0.80	0.990

Table 4a.13. Baseline model settings.

			Likelihood Component Multipliers						
			Fishery		Survey		Recruitment		
Case	Q	catch	length compositions	biomass	length compositions	age compositions	early	ordinary	late
base	1	30	0.5	1	0.5	1	2	1	3

Table 4a.14. Initial parameter values. Values not listed are identical to the corresponding values in the base case.

Case					Fishery				Survey			
					slope		A_{50}		slope		A_{50}	
	$\overline{\ln R_0}$	τ_t	$\overline{\ln F}$	ε_t	f	m	f	m	female	male	female	male
base	15	0	-5	0	12.55	12.55	20.5	20.5	12.55	12.55	20.5	20.5
1	18				0.5	0.5	5	5				
2	12								4.5	4.5	5	5
3			-2		5	5			0.2	0.2	15	15

Table 4a.15. Final parameter estimates.

$\overline{\ln R_0}$ 15.977948

		Sequence # for range of years									
		1	2	3	4	5	6	7	8	9	0
τ_t	1941-1950:							-0.8726	-0.1313	-0.1429	-0.1550
	1951-1960:	-0.1671	-0.1797	-0.1927	-0.2060	-0.2197	-0.2337	-0.0717	-0.0726	-0.0722	0.0104
	1961-1970:	0.0232	0.0268	-0.0158	0.0019	0.3750	0.5139	0.2463	0.1500	0.2356	0.1221
	1971-1980:	0.2246	0.2295	0.1791	0.4376	0.1077	0.4095	-0.0162	0.4275	0.6963	0.3686
	1981-1990:	0.5004	0.1606	0.0222	0.3003	-0.0155	0.2220	-0.0101	-0.3126	-0.5172	-0.5093
	1991-2000:	-0.4918	-0.8781	-0.7170	-0.2306	-0.9156	-0.2932	0.2862	0.1995	-0.1443	0.1003
	2001-2005:	-0.3040	0.9602	0.5482	0.0097	-0.0067					

$\overline{\ln F}$ -4.538197

		Sequence # for range of years									
		1	2	3	4	5	6	7	8	9	0
ε_t	1981-1990:				-1.9542	-3.0599	-3.6746	-2.8474	0.0039	0.3099	0.7040
	1991-2000:	2.0469	1.9707	1.2775	1.1015	0.7555	0.8191	1.3250	0.8827	0.9725	0.1983
	2001-2005:	-0.3251	-0.2641	0.2836	-0.0026	-0.5233					

	Fishery Selectivity	
	A_{50}	slope
females	13.45	24.96
males	10.98	20.75

	Full Coverage Survey Selectivity		Shallow Survey Selectivity	
	A_{50}	slope	A_{50}	slope
females	16.78	0.11	9.44	0.18
males	12.83	0.13	3.94	1.44

Table 4a.16. Model-estimated catch and survey biomass.

	------------catch (t)-------------			------survey biomass (t)-----		
year	**estimated**	**std dev**	**observed**	**estimated**	**std dev**	**observed**
1984	141	18	132	89,126	4,684	68,521
1985	48	6	43	90,353	4,624	
1986	26	3	23	91,638	4,571	
1987	62	8	56	92,640	4,512	63,394
1988	1,071	135	1,087	93,319	4,444	
1989	1,474	185	1,521	92,990	4,341	
1990	2,223	278	2,348	112,580	4,471	96,597
1991	8,165	985	9,741	90,514	4,073	
1992	7,167	873	8,364	84,518	3,755	
1993	3,417	421	3,804	95,228	3,928	85,549
1994	2,787	345	3,053	76,568	3,307	
1995	1,956	244	2,082	74,097	3,161	
1996	2,033	253	2,178	85,134	3,635	79,531
1997	3,279	403	3,659	70,769	2,928	
1998	2,028	253	2,174	68,417	2,800	
1999	2,128	267	2,263	66,978	2,727	74,245
2000	939	119	957	65,707	2,688	
2001	539	68	536	39,635	1,945	32,424
2002	560	71	559	66,021	2,730	
2003	933	118	946	66,710	2,813	99,297
2004	679	86	681	67,165	3,001	
2005	407	52	400	67,917	3,238	80,537

Table 4a.17. Estimated age 3+ population biomass and female spawning biomass.

	2005 SAFE				2003 SAFE	
	Age 3+ Biomass (1000's t)		Female Spawning Biomass (1000's t)		Age 3+ Biomass (1000's t)	Female Spawning Biomass (1000's t)
year	mean	std dev	mean	std dev	mean	mean
1984	171.7	7.6	58.0	3.3	168.4	55.9
1985	172.3	7.5	59.1	3.2	168.9	57.2
1986	173.4	7.5	60.3	3.2	169.1	58.6
1987	173.4	7.4	61.6	3.1	168.6	60.2
1988	172.4	7.4	62.9	3.0	167.0	61.8
1989	169.5	7.3	63.7	3.0	163.5	62.8
1990	165.6	7.2	64.1	3.0	158.8	63.3
1991	160.5	7.1	63.8	2.9	153.0	63.0
1992	148.9	6.8	60.1	2.9	139.6	58.4
1993	138.6	6.6	56.9	2.8	127.7	54.3
1994	133.0	6.5	55.5	2.8	120.9	52.5
1995	127.1	6.4	54.4	2.8	114.7	50.9
1996	123.2	6.3	53.4	2.8	110.0	49.6
1997	121.0	6.3	52.1	2.7	106.6	48.0
1998	118.1	6.4	49.9	2.7	102.6	45.3
1999	116.4	6.6	48.1	2.6	100.3	43.3
2000	115.6	7.0	46.2	2.6	97.8	41.1
2001	115.3	7.3	44.9	2.5	96.9	39.7
2002	120.5	8.8	43.9	2.5	96.8	38.6
2003	124.3	9.3	43.1	2.5	97.2	37.6
2004	127.1	10.4	42.2	2.4		
2005	130.0	11.3	41.9	2.5		

Table 4a.18. Estimated age 3 recruitment for GOA Dover sole.

	2005 SAFE		2003 SAFE
Year	Mean Recruitment (millions)	std dev (millions)	Mean Recruitment (millions)
1984	23.5	4.2	18.5
1985	17.1	3.3	14.8
1986	21.7	3.6	18.9
1987	17.2	2.8	14.2
1988	12.7	2.4	10.5
1989	10.4	2.0	8.6
1990	10.4	2.0	8.8
1991	10.6	2.1	8.8
1992	7.2	1.7	5.5
1993	8.5	2.0	6.8
1994	13.8	3.0	10.5
1995	7.0	2.0	5.1
1996	13.0	3.0	11.3
1997	23.1	4.6	18.6
1998	21.2	4.5	16.8
1999	15.0	4.0	11.3
2000	19.2	6.7	10.8
2001	12.8	5.8	12.2
2002	45.4	29.9	15.9
2003	30.1	13.3	16.8
2004	17.6	7.0	
2005	17.3	6.5	

Table 4a.19. Mean catch (t) for the seven projection scenarios.

year	Catch (t) scenario 1	scenario 2	scenario 3	scenario 4	scenario 5	scenario 6	scenario 7
2005	624	624	624	624	624	624	624
2006	8,482	8,482	4,387	601	0	10,764	8,482
2007	7,524	7,524	4,153	602	0	9,191	7,524
2008	7,011	7,011	4,085	622	0	8,304	8,898
2009	6,509	6,509	3,982	634	0	7,504	7,964
2010	6,314	6,314	3,998	659	0	7,155	7,511
2011	6,302	6,302	4,092	694	0	7,063	7,338
2012	5,884	5,884	3,962	697	0	6,474	6,686
2013	6,255	6,255	4,215	750	0	6,917	7,081
2014	6,193	6,193	4,248	773	0	6,801	6,927
2015	5,837	5,837	4,120	773	0	6,323	6,420
2016	5,538	5,538	4,002	771	0	5,937	6,011
2017	5,291	5,291	3,896	770	0	5,613	5,676
2018	5,085	5,085	3,802	768	0	5,309	5,362

Table 4a.20. Mean female spawning biomass (t) for the seven projection scenarios. The values of $B_{40\%}$ and $B_{35\%}$ are 21,607 t and 18,906 t, respectively.

year	Female spawning biomass (t) scenario 1	scenario 2	scenario 3	scenario 4	scenario 5	scenario 6	scenario 7
2005	41,884	41,884	41,884	41,884	41,884	41,884	41,884
2006	41,922	41,922	41,922	41,922	41,922	41,922	41,922
2007	38,072	38,072	40,254	42,275	42,596	36,858	38,072
2008	35,318	35,318	39,135	42,904	43,524	33,307	35,318
2009	33,353	33,353	38,474	43,842	44,753	30,790	32,364
2010	32,137	32,137	38,293	45,123	46,317	29,201	30,429
2011	31,598	31,598	38,521	46,638	48,100	28,447	29,402
2012	31,333	31,333	38,847	48,128	49,846	28,058	28,799
2013	31,186	31,186	39,096	49,374	51,330	27,880	28,453
2014	30,385	30,385	38,841	50,250	52,468	26,942	27,385
2015	29,257	29,257	38,256	50,805	53,294	25,670	26,013
2016	28,144	28,144	37,555	51,132	53,879	24,482	24,746
2017	27,122	27,122	36,817	51,298	54,288	23,442	23,645
2018	26,218	26,218	36,090	51,356	54,571	22,573	22,727

Table 4a.21. Mean fishing mortality for the seven projection scenarios.

	Fishing mortality						
year	scenario 1	scenario 2	scenario 3	scenario 4	scenario 5	scenario 6	scenario 7
2005	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097
2006	0.1418	0.1418	0.0709	0.0094	0.0000	0.1835	0.1418
2007	0.1418	0.1418	0.0709	0.0094	0.0000	0.1835	0.1418
2008	0.1418	0.1418	0.0709	0.0094	0.0000	0.1835	0.1835
2009	0.1418	0.1418	0.0709	0.0094	0.0000	0.1835	0.1835
2010	0.1418	0.1418	0.0709	0.0094	0.0000	0.1835	0.1835
2011	0.1418	0.1418	0.0709	0.0094	0.0000	0.1835	0.1835
2012	0.1418	0.1418	0.0709	0.0094	0.0000	0.1835	0.1835
2013	0.1418	0.1418	0.0709	0.0094	0.0000	0.1835	0.1835
2014	0.1418	0.1418	0.0709	0.0094	0.0000	0.1835	0.1835
2015	0.1418	0.1418	0.0709	0.0094	0.0000	0.1835	0.1835
2016	0.1418	0.1418	0.0709	0.0094	0.0000	0.1835	0.1835
2017	0.1418	0.1418	0.0709	0.0094	0.0000	0.1828	0.1830
2018	0.1418	0.1418	0.0709	0.0094	0.0000	0.1801	0.1806

Figures

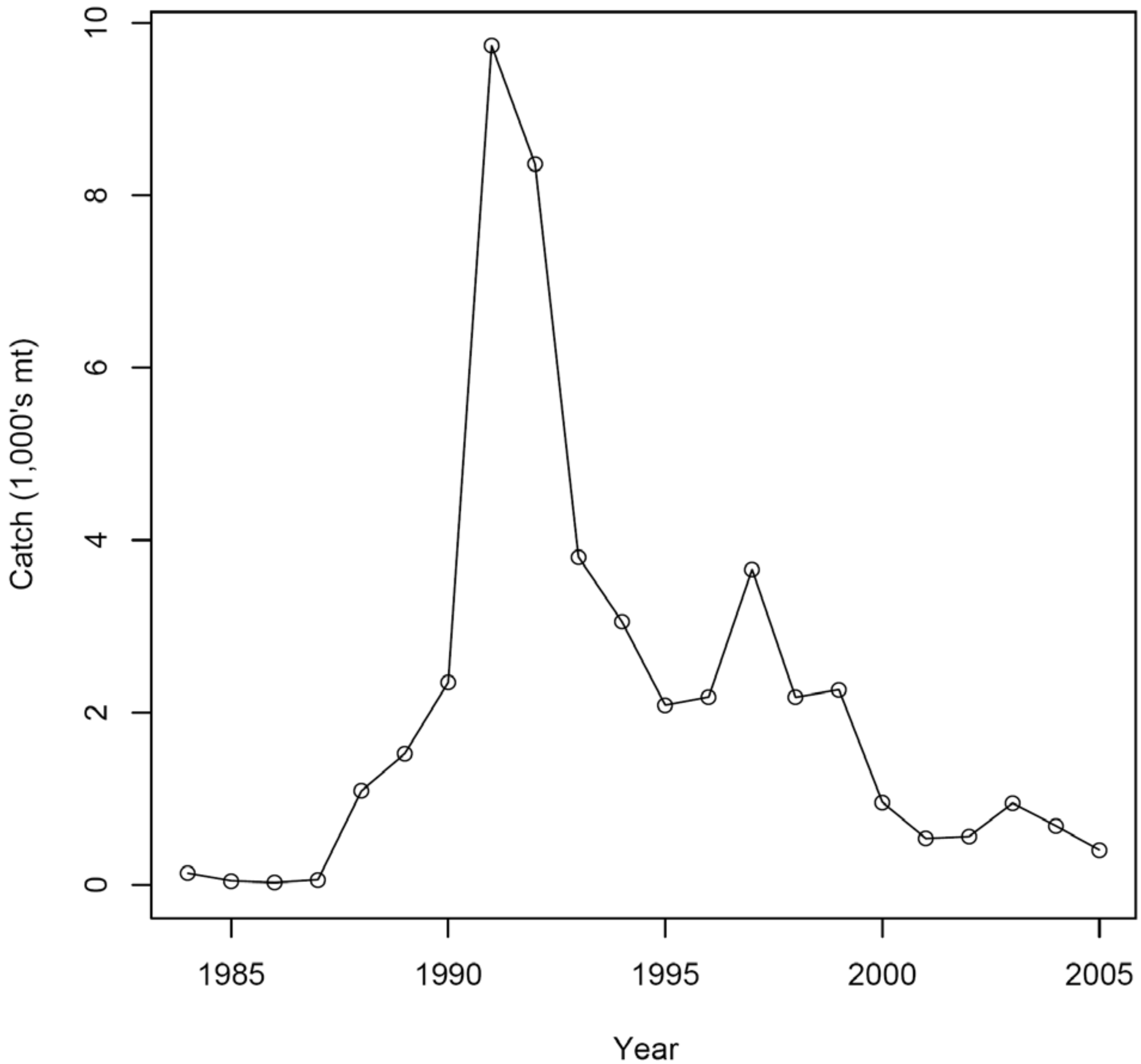

Figure 4a.1. Catch history for Dover sole in the Gulf of Alaska.

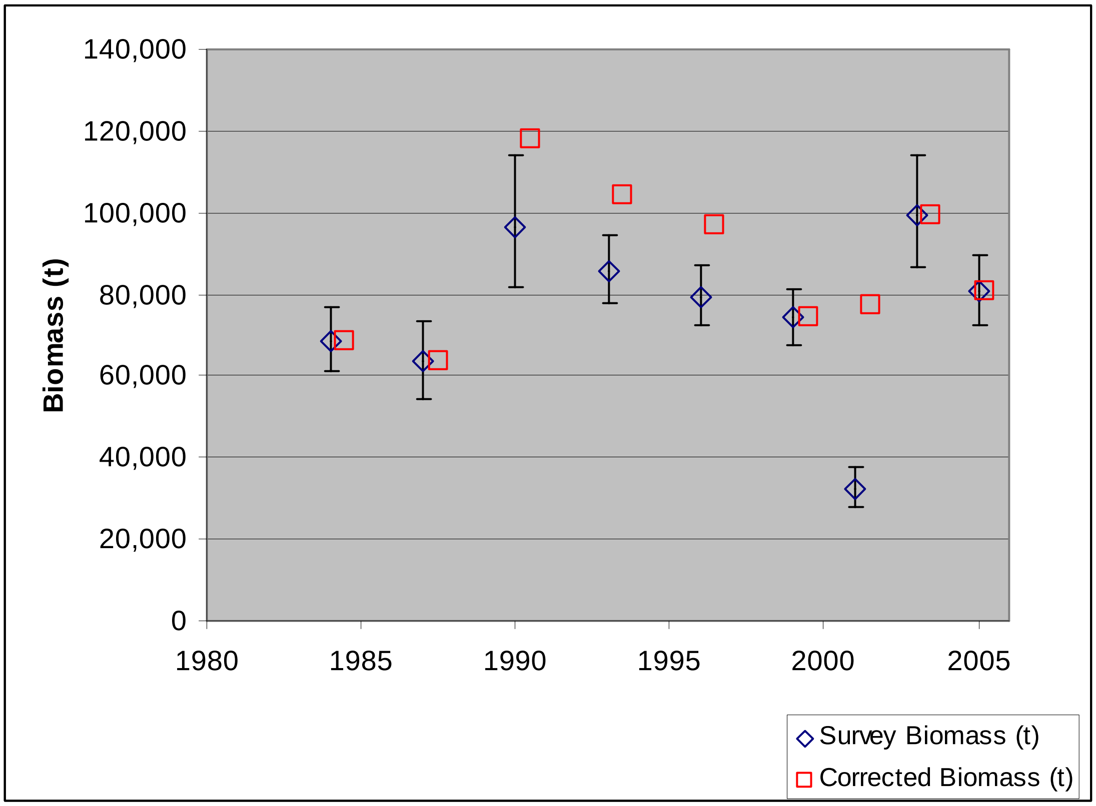

Figure 4a.2. Estimated biomass and 95% CIs from NMFS Gulf of Alaska groundfish trawl surveys. "Survey biomass" values are uncorrected for differences in coverage by depth or region. "Corrected biomass" values are scaled for differences in survey coverage.

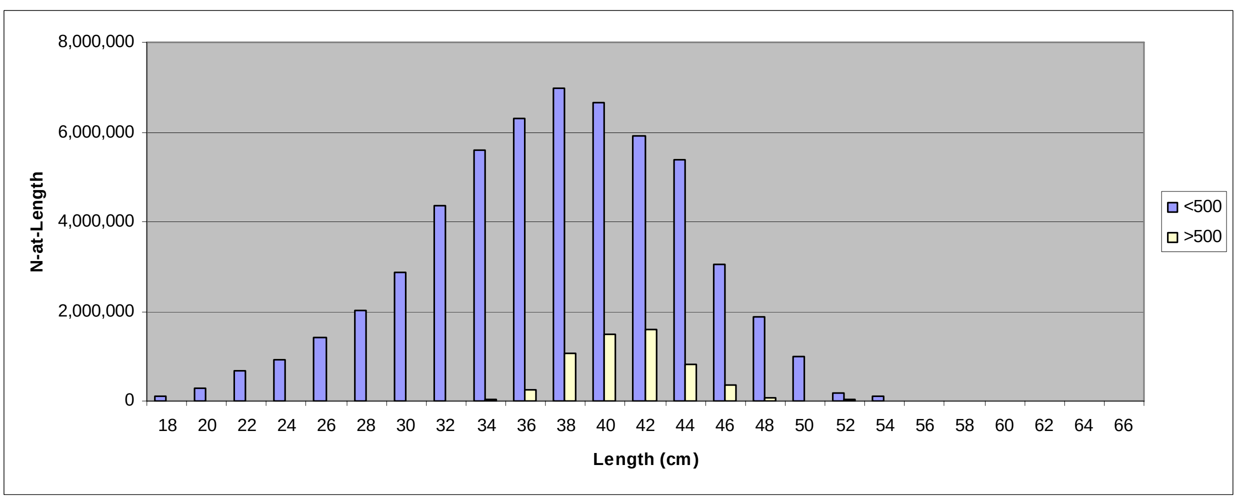

Figure 4a.3. Survey length compositions by depth range for male Dover sole from the 2005 survey. Depth range 1-500 m = blue bars; 500-1000 m = yellow bars.

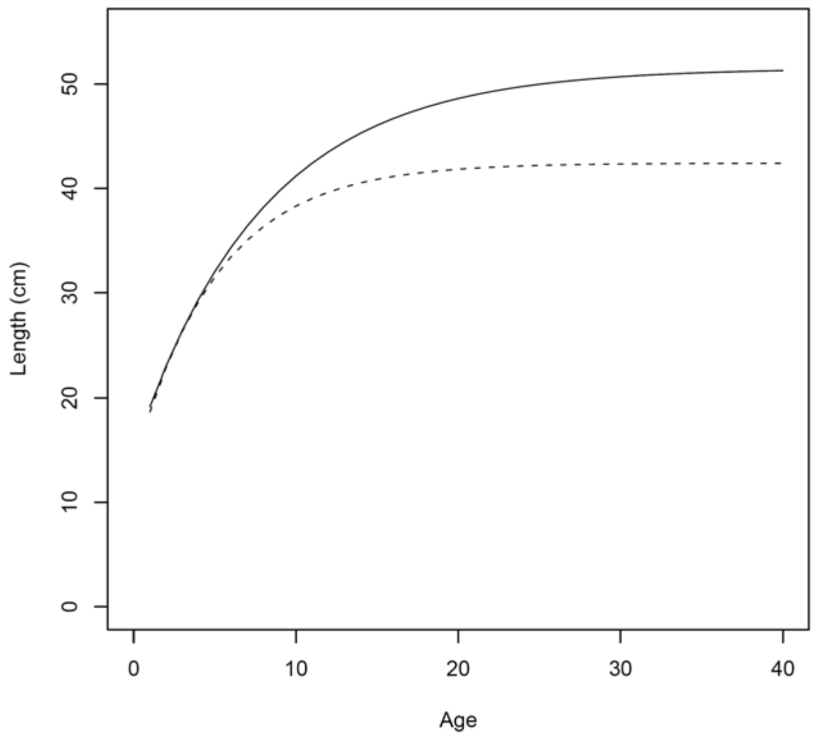

Figure 4a.4. Growth for GOA Dover sole: females solid line, males dotted line.

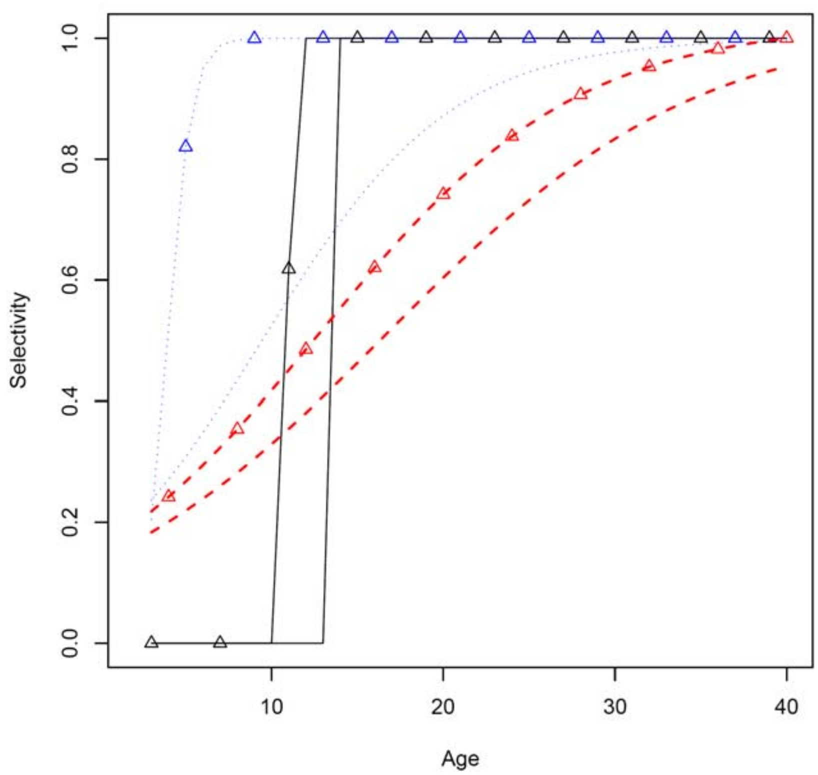

Figure 4a.5. Selectivities for GOA Dover sole for the fishery (solid line) and surveys (full coverage surveys = dashed red lines, shallow surveys = dotted blue lines). Curves corresponding to males are indicated by triangles, plain curves correspond to females.

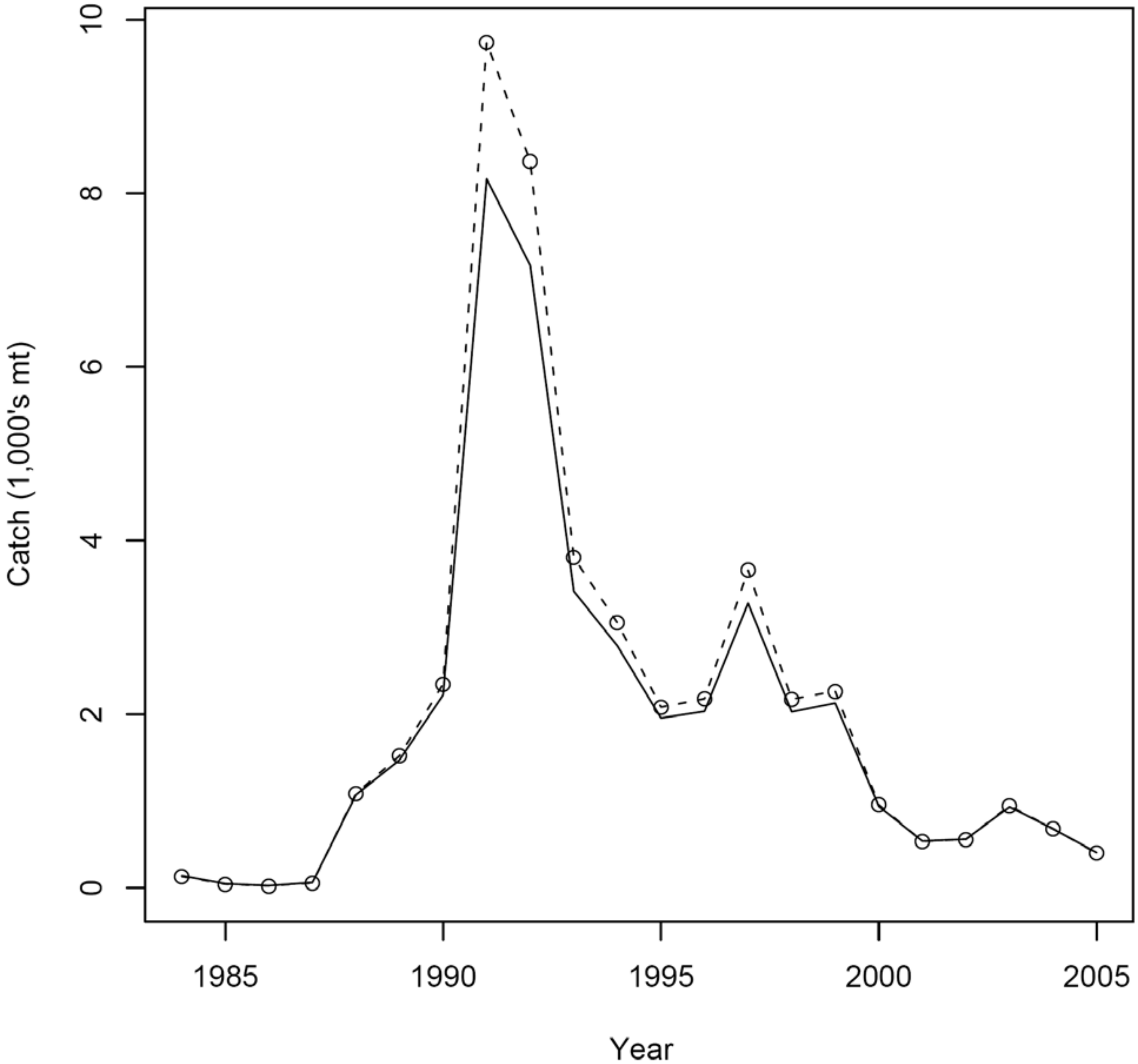

Figure 4a.6. Predicted and observed annual catches for GOA Dover sole. Predicted catch = solid line, observed catch = dotted line with circles.

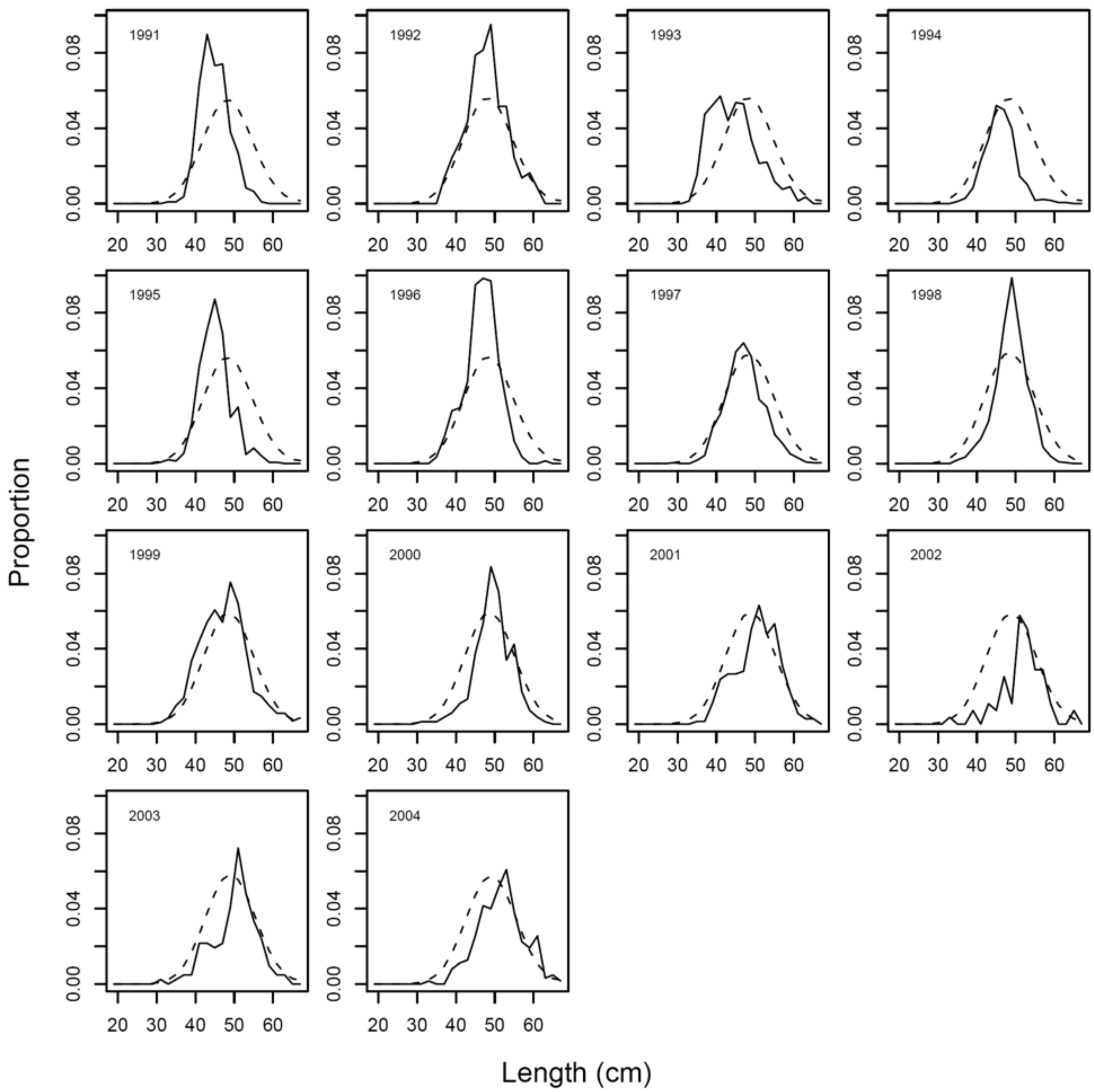

Figure 4a.7. Fits to female GOA Dover sole fishery length composition data. Dashed lines represent the model prediction, solid lines represent the data.

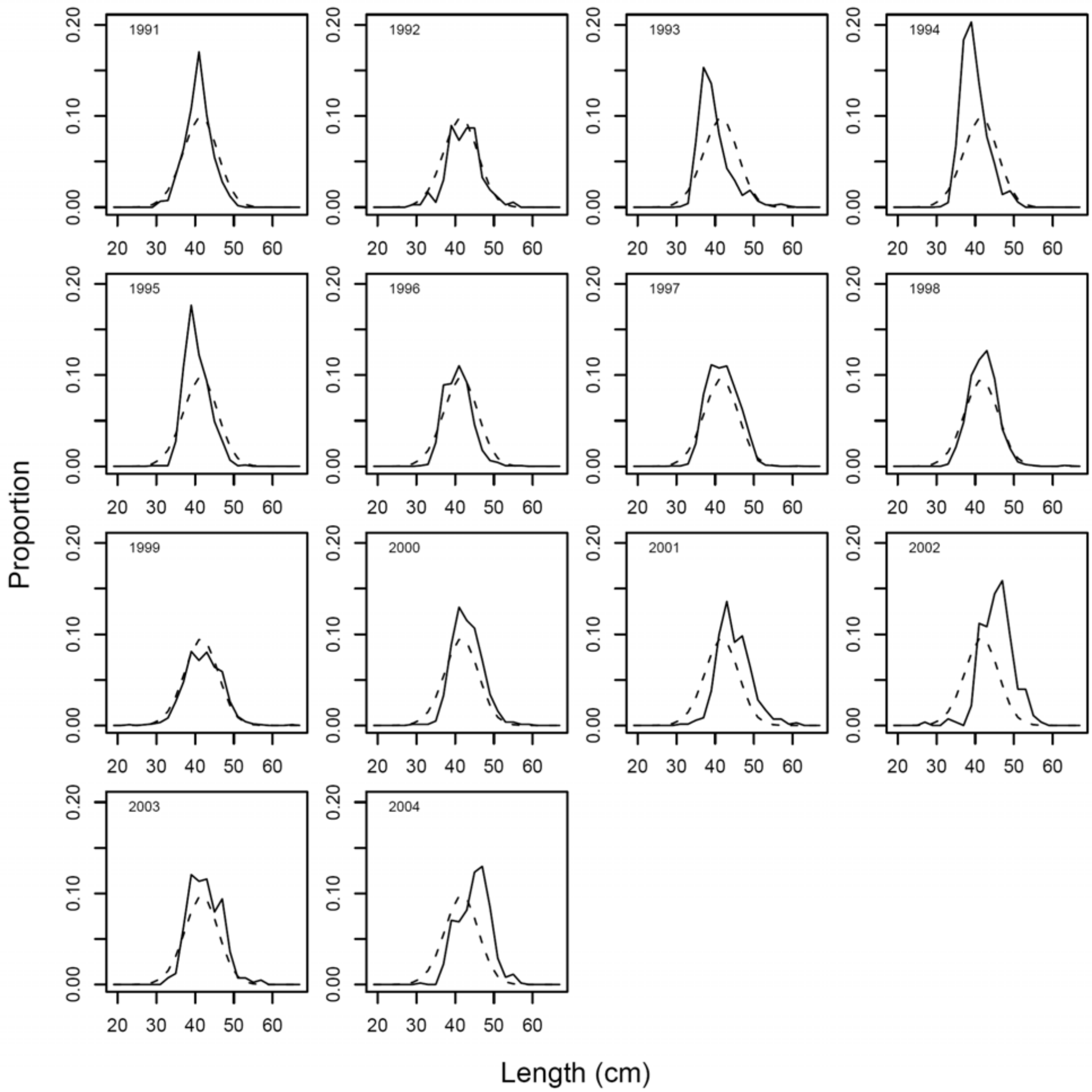

Figure 4a.8. Fits to male GOA Dover sole fishery length composition data. Dashed lines represent the model prediction, solid lines represent the data.

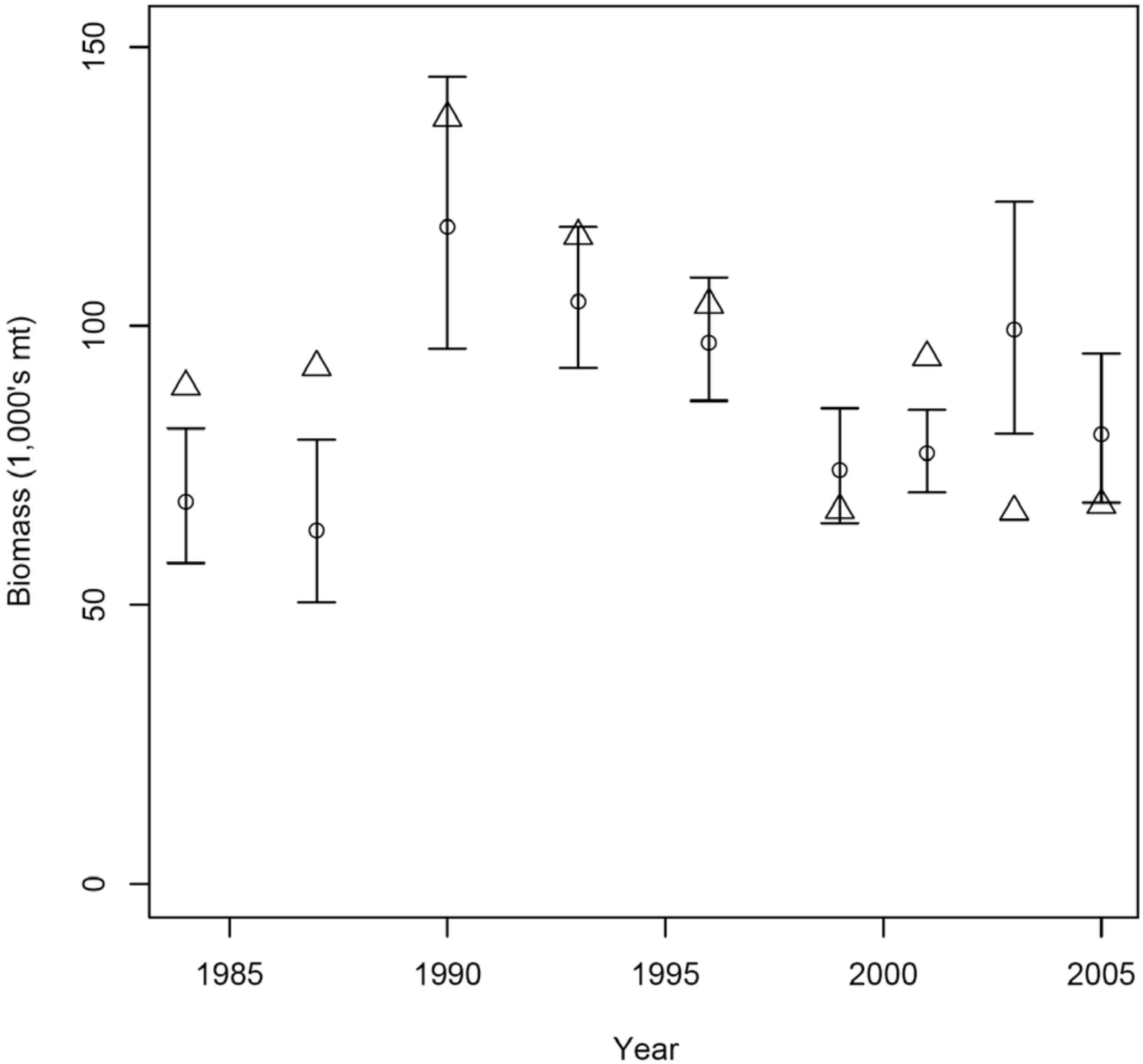

Fig. 4a.9. Predicted and observed survey biomass for GOA Dover sole. Predicted survey biomass = triangles, observed survey biomass = circles (error bars are approximate lognormal 95% confidence intervals). Observed survey biomass has been corrected for differences in availability (see Fig. 4a.2).

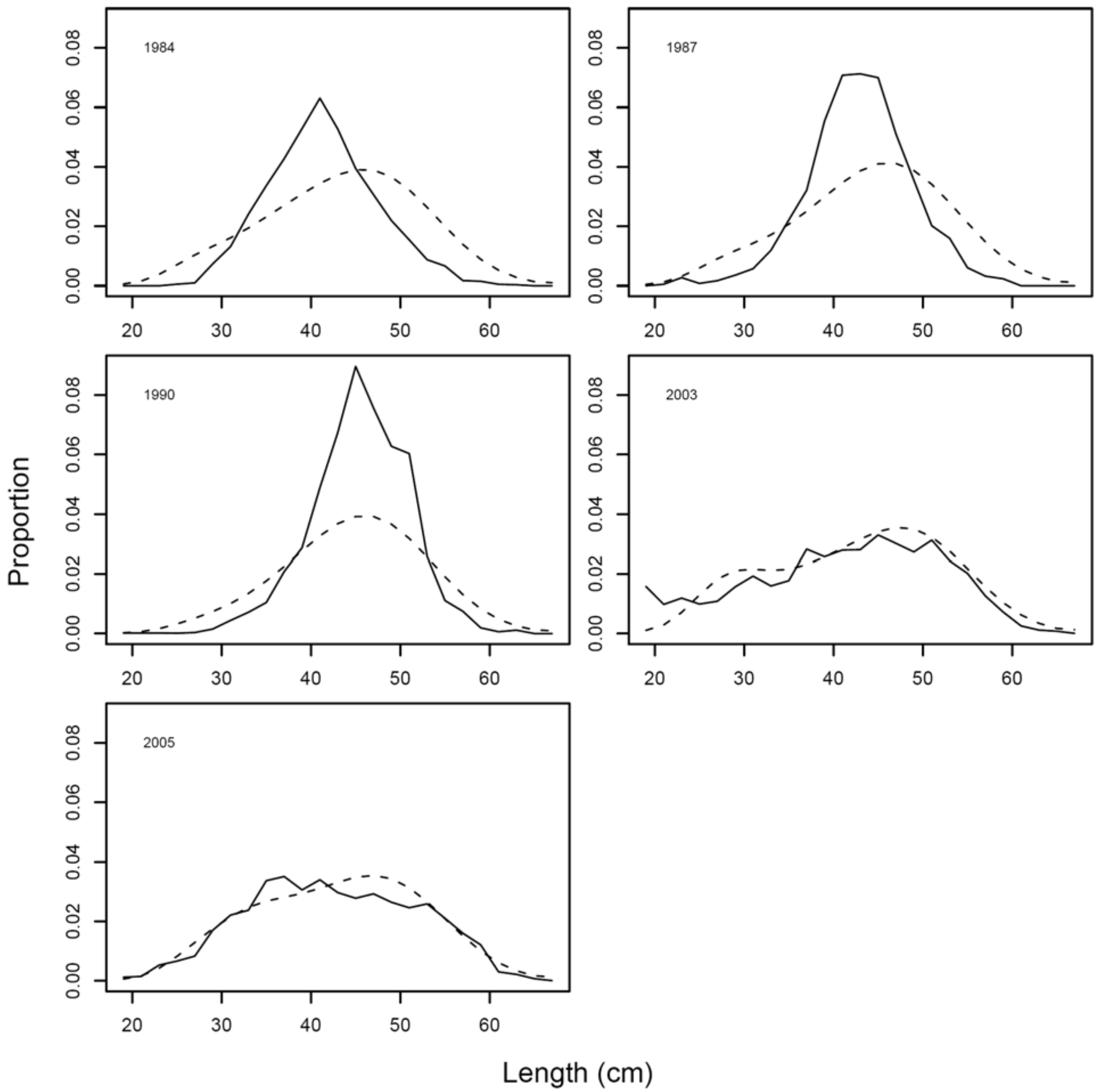

Figure 4a.10. Fit to the female GOA Dover sole survey length composition data. Dashed lines represent the model prediction, solid lines represent the data.

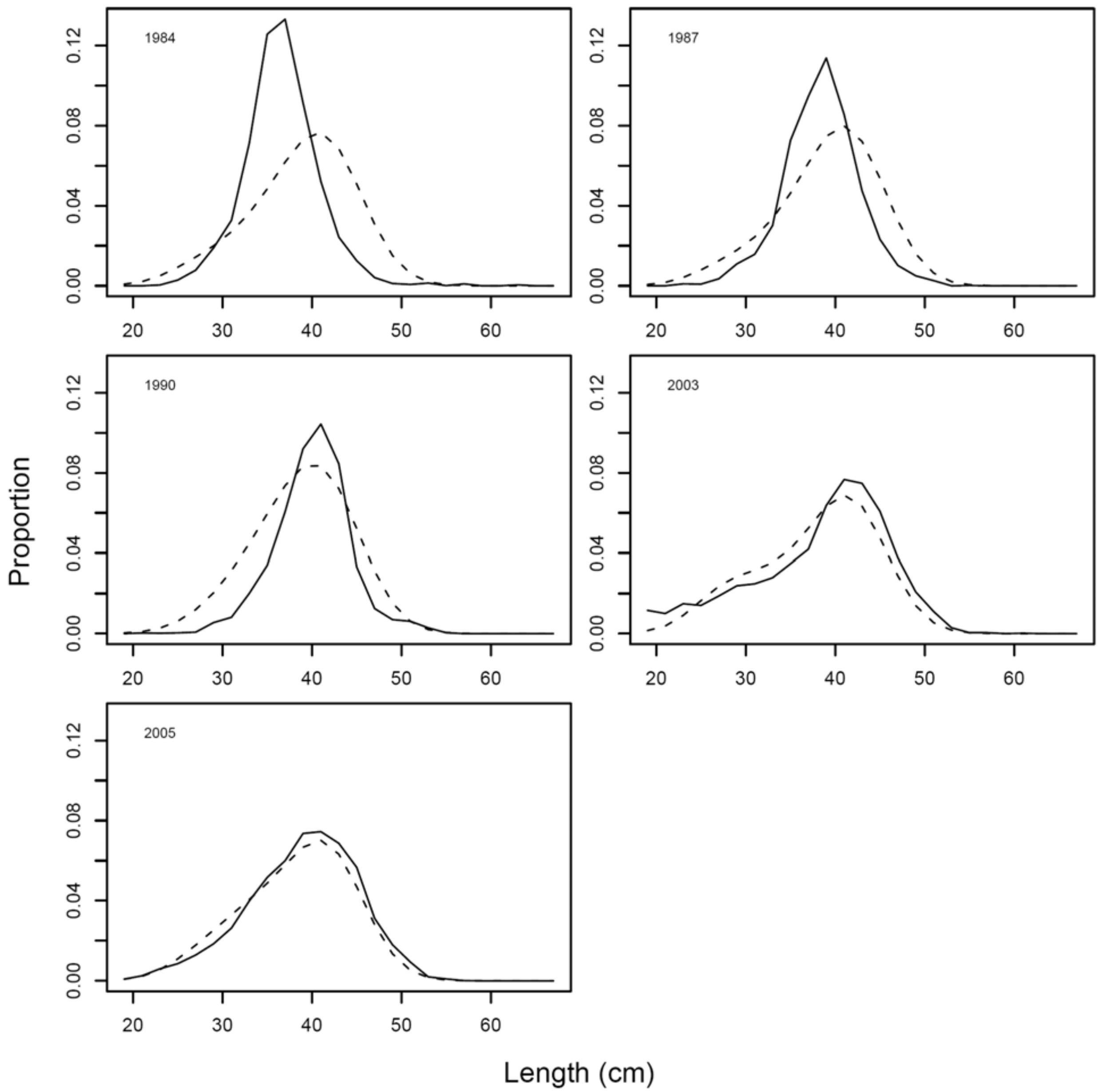

Figure 4a.11. Fit to the male GOA Dover sole survey length composition data. Dashed lines represent the model prediction, solid lines represent the data.

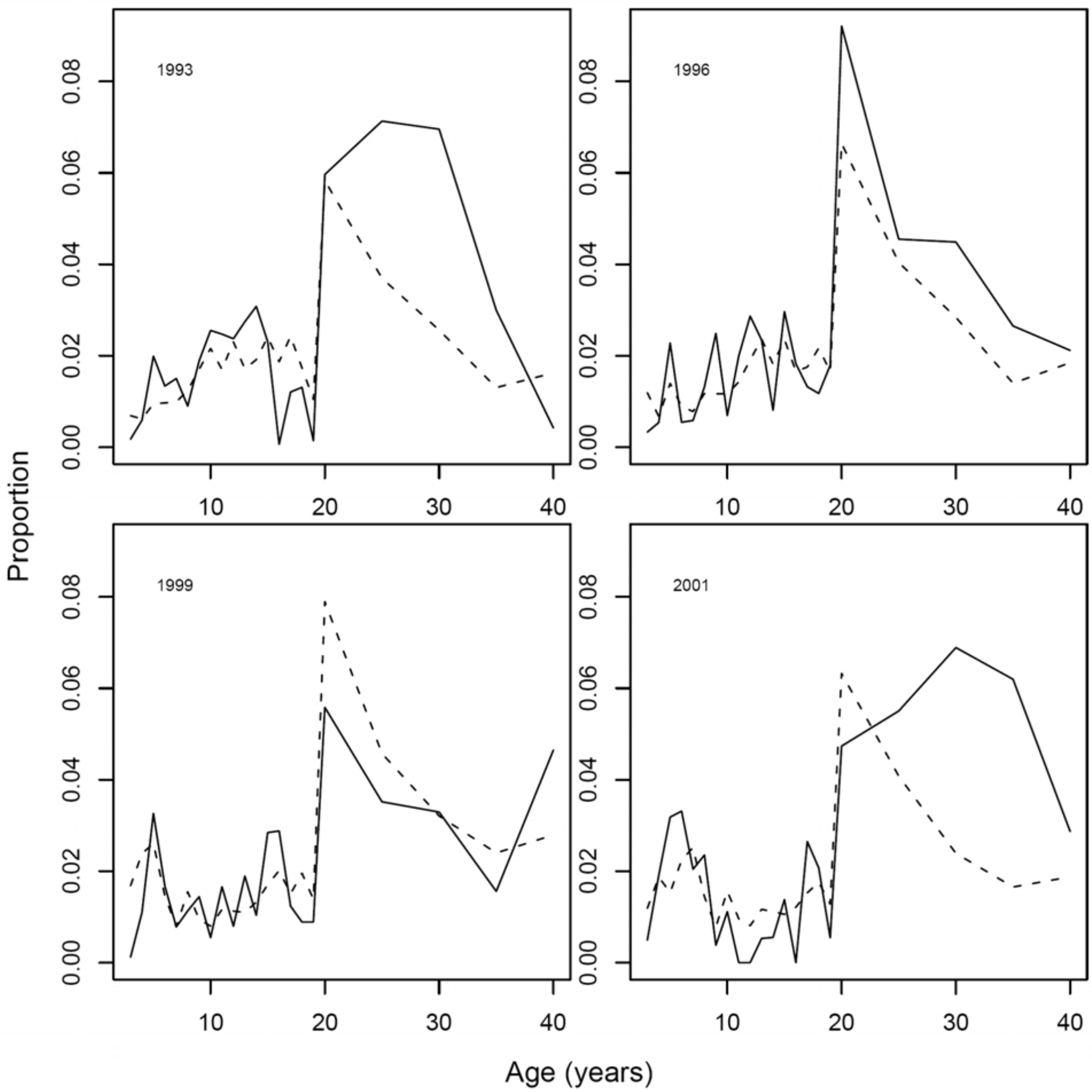

Figure 4a.12. Fit to the female survey GOA Dover sole age composition data. Dashed lines represent the model prediction, solid lines represent the data.

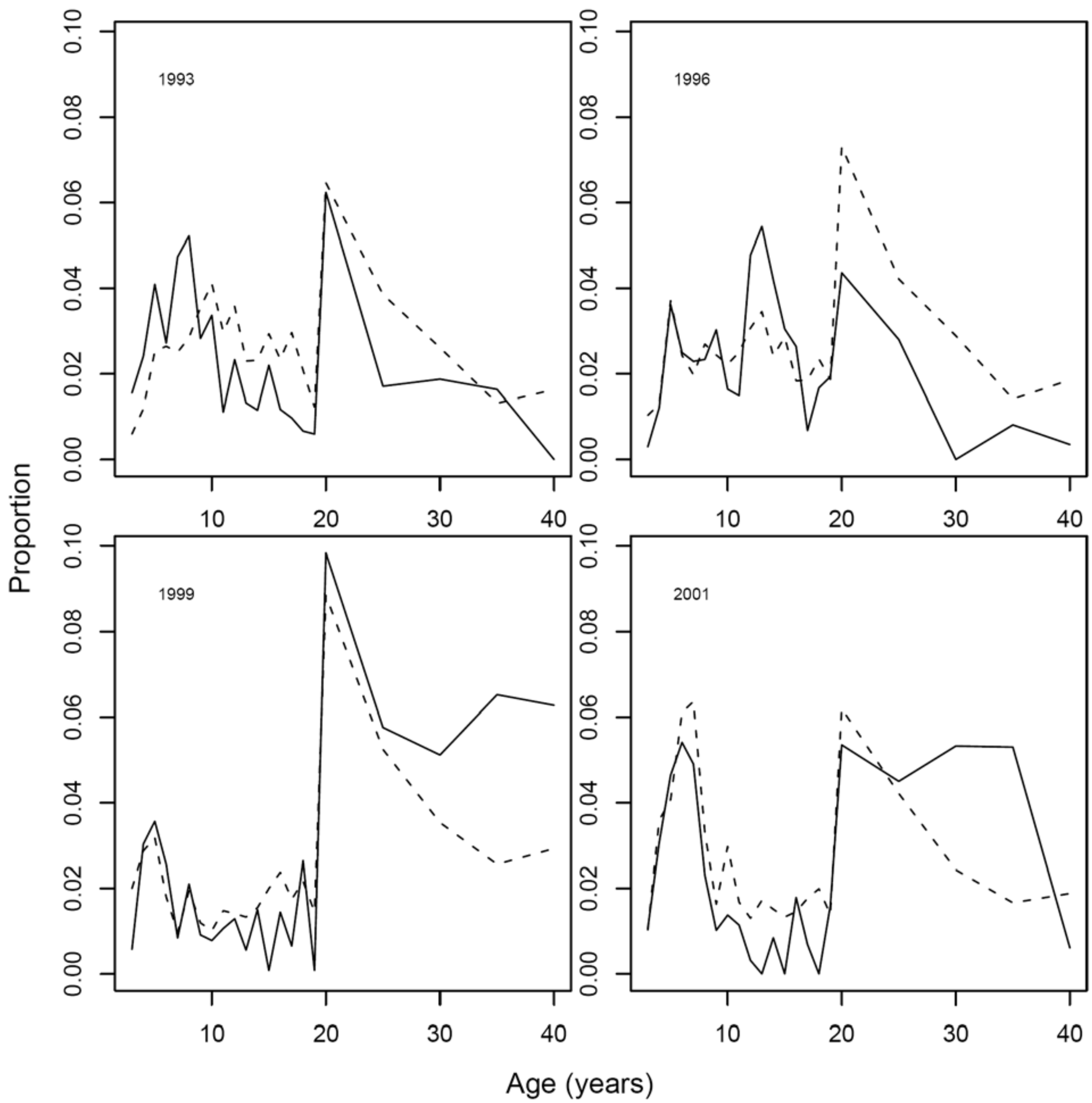

Figure 4a.13. Fit to the male survey GOA Dover sole age composition data. Dashed lines represent the model prediction, solid lines represent the data.

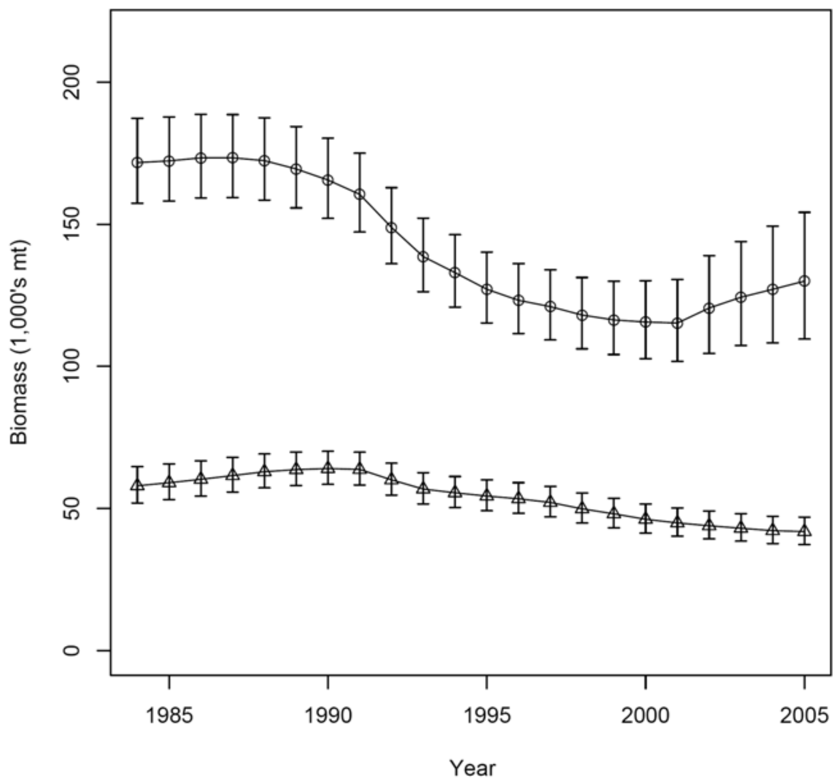

Figure 4a.14. Estimated age 3+ biomass (circles) and female spawning biomass (triangles) for GOA Dover sole. Error bars are approximate lognormal 95% confidence intervals.

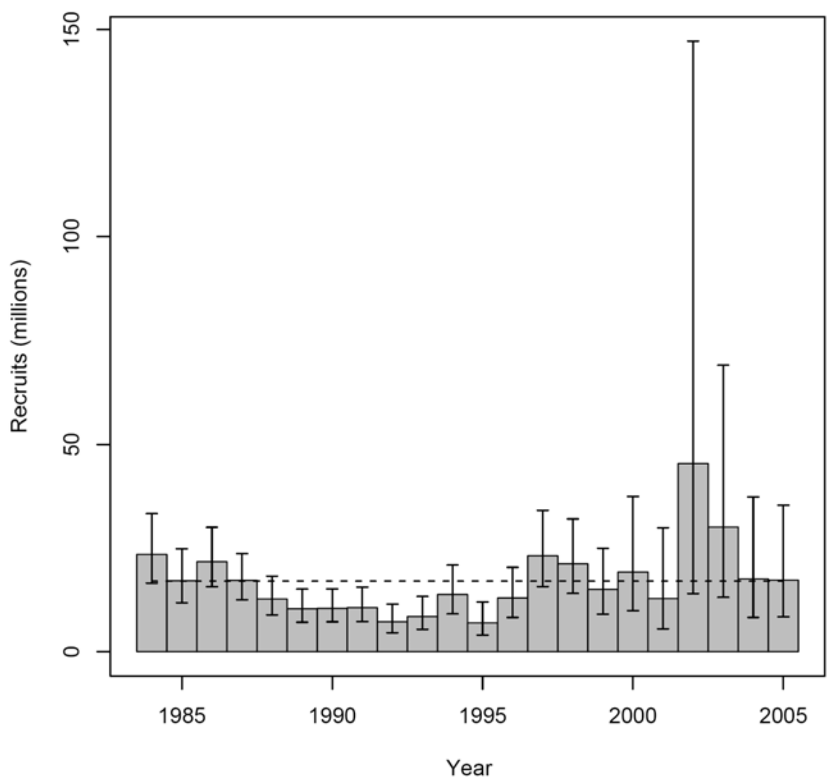

Figure 4a.15. Estimated age 3 recruitments of GOA Dover sole with approximate 95% lognormal confidence intervals. Horizontal line is mean recruitment.

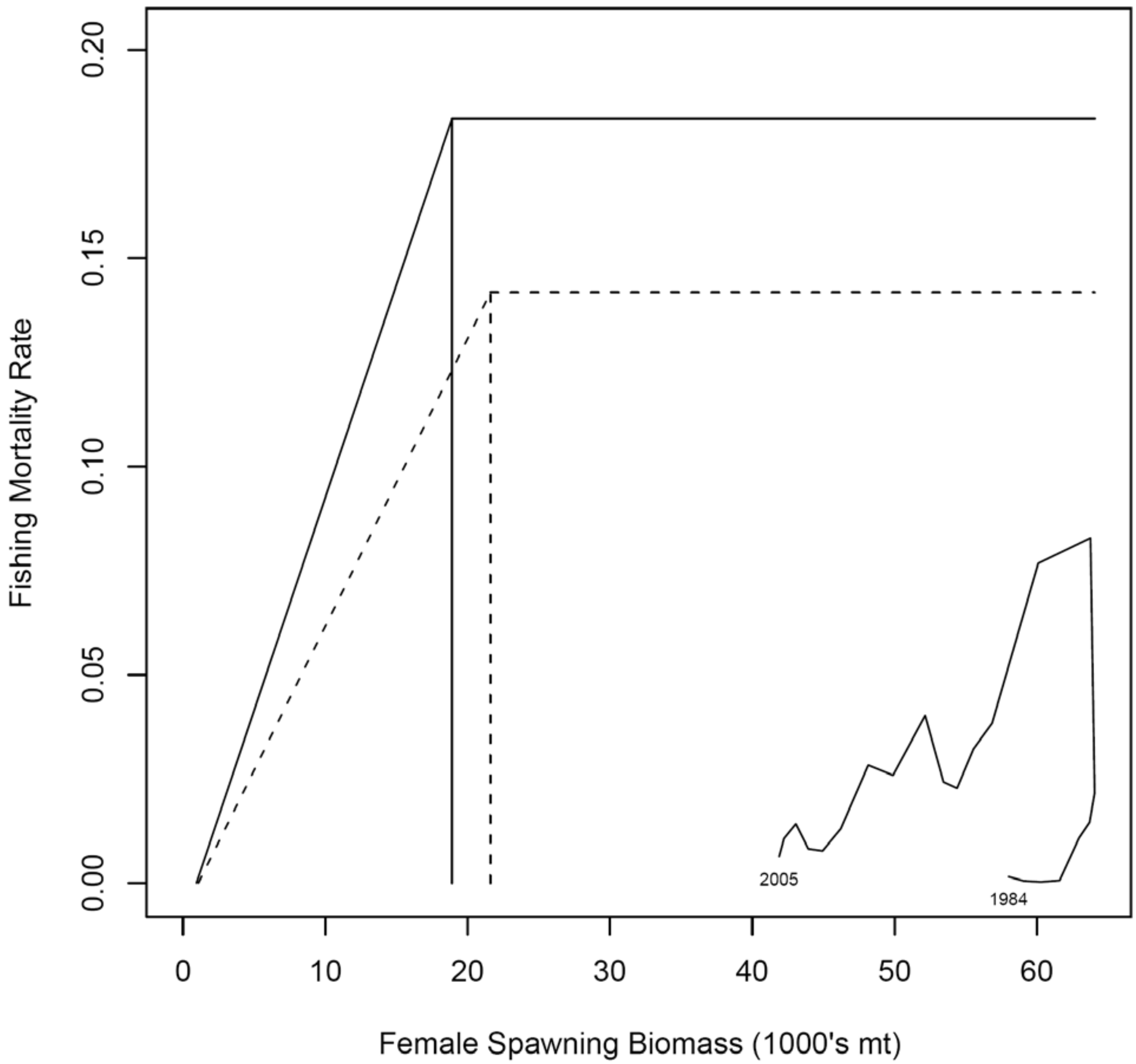

Figure 4a.16. Control rule plot of estimated fishing mortality versus estimated female spawning biomass for GOA Dover sole. F_{OFL} = horizontal solid line, $F_{max\ ABC}$ = horizontal dashed line. $B_{35\%}$ = vertical solid line, $B_{40\%}$ = vertical dashed line.

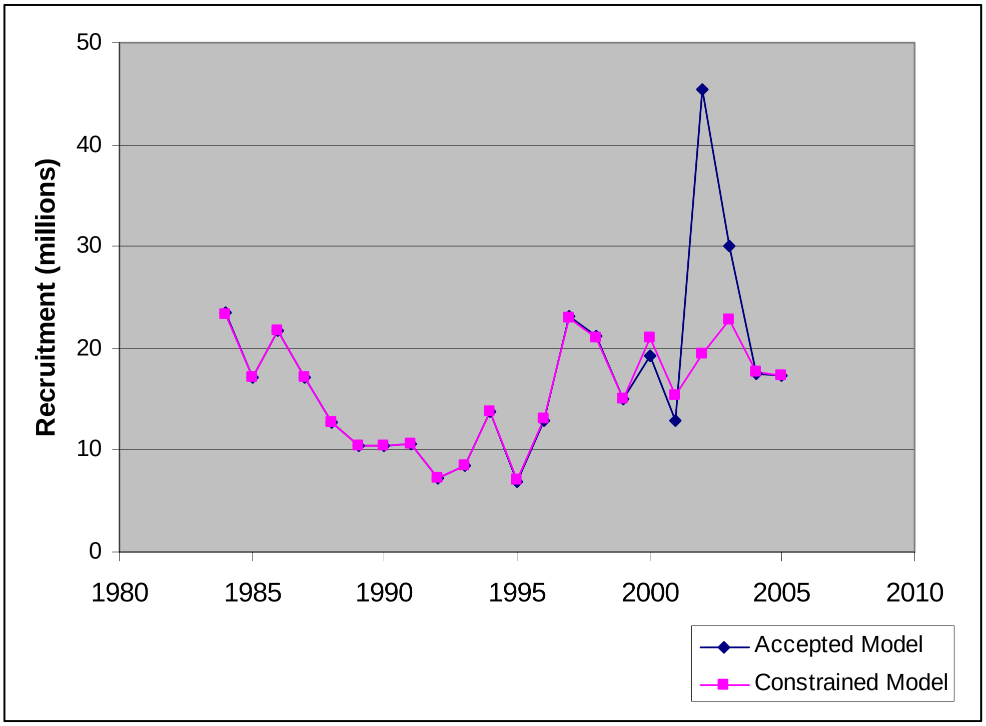

Figure 4a.17. Comparison of estimated age 3 recruitments for the "accepted model" (AM) and the "constrained recruitment" model (CRM).

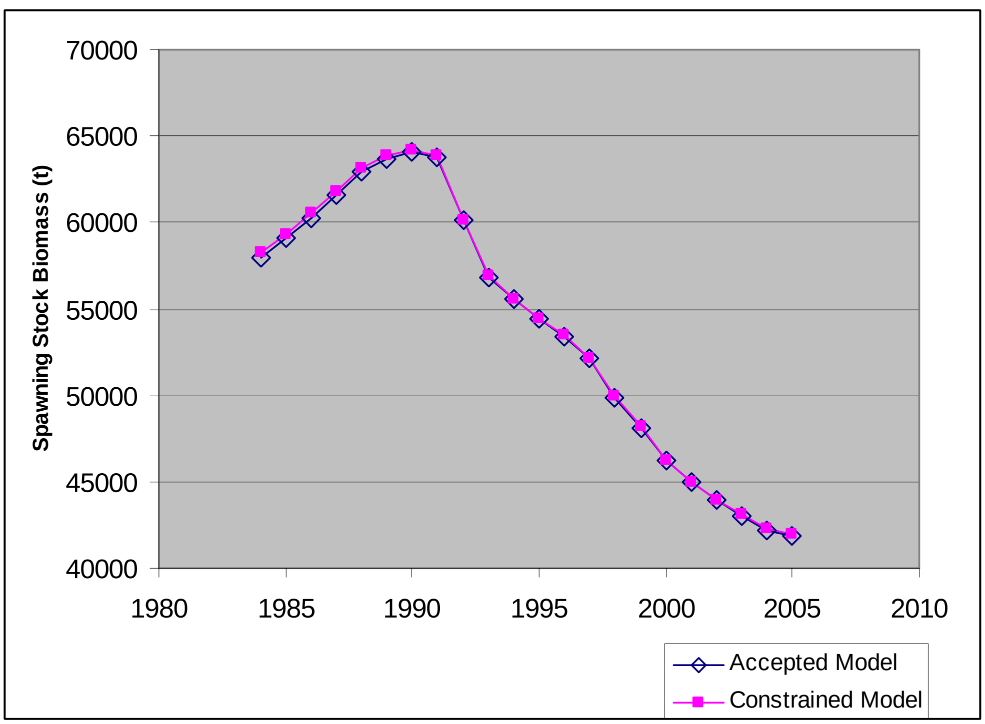

Figure 4a.18. Comparison of estimated female spawning biomass for the "accepted model" (AM) and the "constrained recruitment" model (CRM).

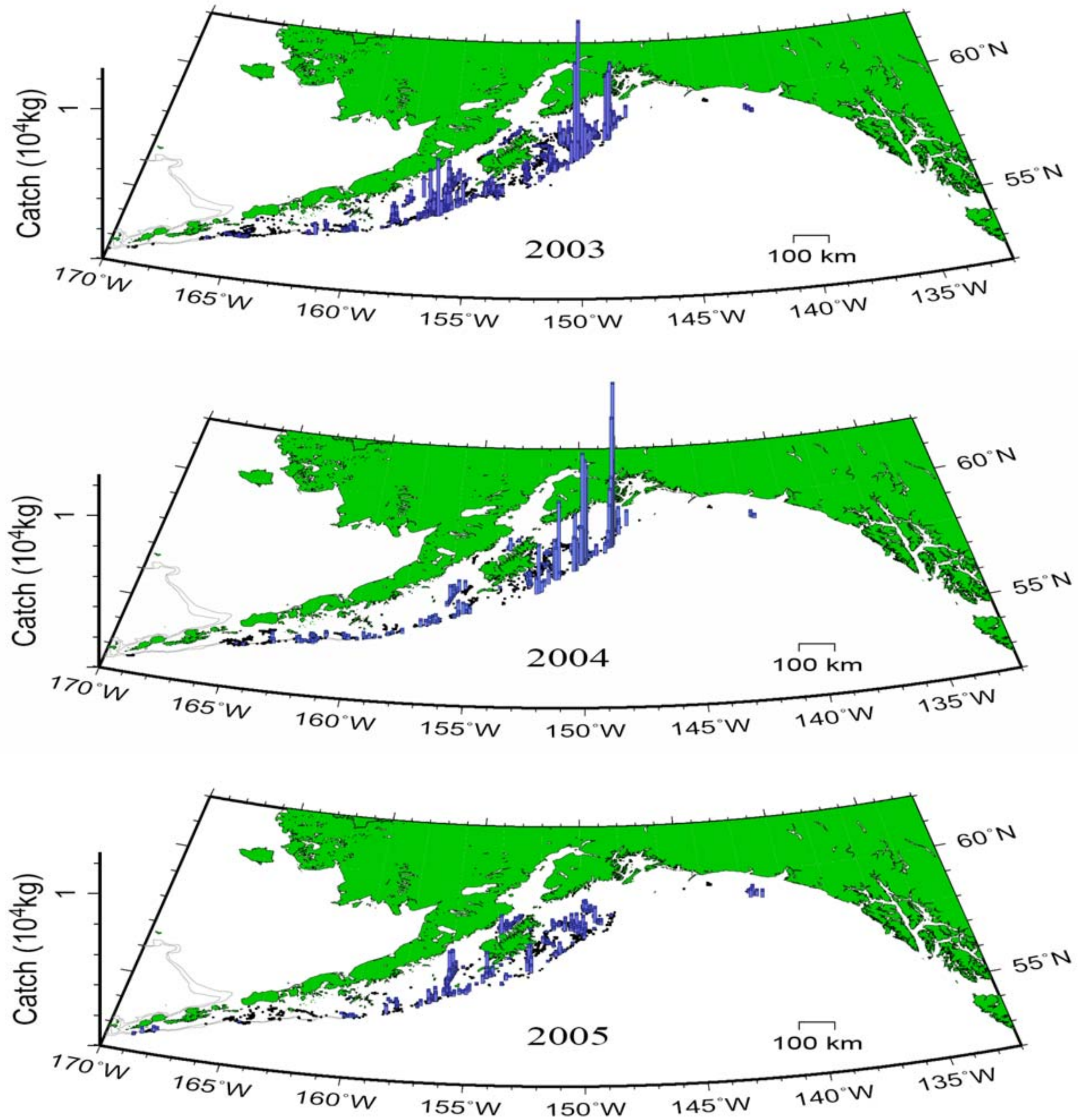

Figure 4a.19. Annual patterns of Dover sole catch in the fishery for 2003-2005 (from NMFS Observer Program data).

Appendix A.

Table A.1. List of variables and their definitions used in the model.

Variable	Definition
T	number of years in the model
A	number of age classes
L	number of length classes
t	time index (1984≤t≤2005)
a	age index (1≤a≤A; a=1 corresponds to age 3)
x	sex index (1≤x≤2; 1=male, 2=female)
l	length index (1≤l≤L)
$\{t^S\}$	set of years for which survey biomass data is available
$\{t^{F,A}\}$	set of years for which fishery age composition data is available
$\{t^{F,L}\}$	set of years for which fishery length composition data is available
$\{t^{S,A}\}$	set of years for which survey age composition data is available
$\{t^{S,L}\}$	set of years for which survey length composition data is available
$L^x_{l,a}$	element of length-age matrix (proportion of sex x fish in age class a that are in length class l)
$w_{x,a}$	mean body weight (kg) of sex x fish in age group a.
ϕ_a	proportion of females mature at age a
R_t	recruitment in year t
$\overline{\ln R_0}$	mean value of log-transformed recruitment
τ_t	recruitment deviation in year t
$N_{t,x,a}$	number of fish of sex x and age class a in year t
$C_{t,x,a}$	catch (number) of fish of sex x and age class a in year t
$p^{F,A}{}_{t,x,a}$	proportion of the total catch in year t that is sex x and in age class a
$p^{F,L}{}_{t,x,l}$	proportion of the total catch in year t that is sex x and in length class l
$p^{S,A}{}_{t,x,a}$	proportion of the survey biomass in year t that is sex x and in age group a
$p^{S,L}{}_{t,x,l}$	proportion of the survey biomass in year t that is sex x and in age group a
C_t	Total catch in year t (observed)
Y_t	total yield(tons) in year t
$F_{t,x,a}$	instantaneous fishing mortality rate for sex x and age group a in year t
M	Instantananeous natural mortality rate
$\overline{\ln F}$	mean value of log-transformed fishing mortality
ε_t	deviations in fishing mortality rate in year t
$Z_{t,x,a}$	Instantantaneous total mortality for sex x and age group a in year t
$s^F{}_{x,a}$	fishery selectivity for sex x and age group a
$s^S{}_{x,a}$	survey selectivity for sex x and age group a

Table A.2. Model equations describing the populations dynamics.

τ_t	Random deviate associated with recruitment.
$N_{t,x,1} = R_t = \exp\left(\overline{\ln R_0} + \tau_t\right)$	Recruitment (assumed equal for males and females).
$N_{t+1,x,a+1} = N_{t,x,a} e^{-Z_{t,x,a}}$	Numbers at age.
$N_{t+1,x,A} = N_{t,x,A-1} e^{-Z_{t,x,A-1}} + N_{t,x,A} e^{-Z_{t,x,A}}$	Numbers in "plus" group.
$C_{t,x,a} = \frac{F_{t,x,a}}{Z_{t,x,a}} (1 - e^{-Z_{t,x,a}}) N_{t,x,a}$	Catch at age (in numbers caught).
$C_t = \sum_{x=1}^{2} \sum_{a=1}^{A} w_{x,a} C_{t,x,a}$	Total catch in tons (i.e., yield).
$FSB_t = \sum_{a=1}^{A} w_{1,a} \phi_a N_{t,1,a}$	Female spawning biomass.
$Z_{t,x,a} = F_{t,x,a} + M$	Total mortality.
$F_{t,x,a} = s^F_{x,a} \cdot \exp\left(\overline{\ln F} + \varepsilon_t\right)$	Fishing mortality.
$\varepsilon_t \sim N(0, \sigma_F^2)$	Random deviate associated with fishing mortality.
$s^F_{x,a} = \frac{1}{1 + e^{(-b^F_x (age - {}_{50}A^F_x))}}$	Fishery selectivity- 2 parameter ascending logistic - separate for males and females.
$s^S_{x,a} = \frac{1}{1 + e^{(-b^S_x (age - {}_{50}A^S_x))}}$	Survey selectivity- 2 parameter ascending logistic - separate for males and females.
$N^S{}_{t,x,a} = Q\, s^S_{x,a} N_{t,x,a}$	Survey numbers for sex *x*, age *a* at time *t*.
$SB_t = \sum_{x=1}^{2} \sum_{a=1}^{A} w_{x,a}\ N^S{}_{t,x,a}$	Total survey biomass.
$p^{F,A}_{t,x,a} = C_{t,x,a} / \sum_{x=1}^{2} \sum_{a=1}^{A} C_{t,x,a}$	Proportion at age in the catch.
$p^{F,L}_{t,x,l} = \sum_{a=1}^{A} L^x_{l,a} \cdot p^{F,A}_{t,x,a}$	Proportion at length in the catch.
$p^{S,A}_{t,x,a} = N^S{}_{t,x,a} / \sum_{x=1}^{2} \sum_{a=1}^{A} N^S{}_{t,x,a}$	Proportion at age in the survey.
$p^{S,L}_{t,x,l} = \sum_{a=1}^{A} L^x_{l,a} \cdot p^{S,A}_{t,x,a}$	Proportion at length in the survey.

Table A.3. Likelihood components.

Component	Description
$\sum_{t=1}^{T}\left[\log(C_t^{obs})-\log(C_t)\right]^2$	Catch; uses a lognormal distribution.
$\sum_{t\in\{t^{F,A}\}}\sum_{x=1}^{2}\sum_{a=1}^{A} n_{t,x}^{samp}\cdot p_{t,x,a}^{F,A,obs}\cdot\log(p_{t,x,a}^{F,A})$ - offset	Fishery age composition; uses a multinomial distribution. n^{samp} is the observed sample size.
$\sum_{t\in\{t^{F,L}\}}\sum_{x=1}^{2}\sum_{l=1}^{L} n_{t,x}^{samp}\cdot p_{t,x,l}^{F,L,obs}\cdot\log(p_{t,x,l}^{F,L})$ - offset	Fishery length composition; uses a multinomial distribution. n^{samp} is the observed sample size.
$\sum_{t\in\{t^{F,A}\}}\sum_{x=1}^{2}\sum_{a=1}^{A} n_{t,x}^{samp}\cdot p_{t,x,a}^{S,A,obs}\cdot\log(p_{t,x,a}^{S,A})$ - offset	Survey age composition; uses a multinomial distribution. n^{samp} is the observed sample size.
$\sum_{t\in\{t^{F,L}\}}\sum_{x=1}^{2}\sum_{l=1}^{L} n_{t,x}^{samp}\cdot p_{t,x,l}^{S,L,obs}\cdot\log(p_{t,x,l}^{S,L})$ - offset	Survey length composition; uses a multinomial distribution. n^{samp} is the observed sample size.
$\text{offset}=\sum_{t}\sum_{x=1}^{2}\sum_{a=1}^{A} n_{t,x}^{samp}\cdot p_{t,x,a}^{obs}\cdot\log(p_{t,x,a}^{obs}))$	The offset constants for age composition components are calculated from the observed proportions and the sample sizes. A similar formula is used for length composition component offsets.
$\sum_{t\in\{t^{S}\}}\left[\frac{\log\left[\frac{SB_t^{obs}}{SB_t}\right]}{\sqrt{2}\cdot s.d.(\log(SB_t^{obs}))}\right]^2$	Survey biomass; uses a lognormal distribution.
$\sum_{t=1984}^{2002}(\tau_t)^2$	Recruitment; uses a lognormal distribution, since τ_t is on a log scale.
$\sum_{t=2003}^{2005}(\tau_t)^2$	"Late" recruitment; uses a lognormal distribution, since τ_t is on a log scale.
$\sum_{t=1947}^{1983}(\tau_t)^2$	"Early" recruitment; uses a lognormal distribution, since τ_t is on a log scale. Determines age composition at starting year of model.

Table A.4. Fixed parameters in the model.

Parameter	Description
$M = 0.085$	Natural mortality
$Q = 1.0$	Survey catchability
L_{inf} , t_0 , k , cv of length at age 3 and age 40 for males and females	von Bertalanffy Growth parameters estimated from the 1984-1996 survey length and age data.

Table A.5. Estimated parameters for the model. A total of 72 parameters were estimated in the model.

Parameter	Subscript range	Total no. of Parameters	Description
$\log(R_0)$	na	1	log of the geometric mean value of age 3 recruitment
τ_t	$1947 \le t \le 2005$	59 (22 + 37 from initial age composition)	Recruitment deviation in year t (log-scale)
$\log(f_0)$	Na	1	log of the geometric mean value of fishing mortality
ε_t	$1984 \le t \le 2005$	22	deviations in fishing mortality rate in year t
b^F_x , ${}_{50}A^F_x$	$1 \le x \le 2$	4	selectivity parameters (slope and age at 50% selected) for the fishery for males and females.
b^S_x , ${}_{50}A^S_x$	$1 \le x \le 2$	8	selectivity parameters (slope and age at 50% selected) for survey data, for males and females. Curves for shallow and full coverage surveys were treated separately.

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